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Effect of Particle Size of Some Insecticides on Their Toxicity to the Codling Moth Larva*

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The possible effect of particle size on the toxicological value of a given insecticide has been given some thought from time to time, but few actual tests have been made on classified materials. It would appear that a better understanding of this relationship could be had from experimental evidence obtained under carefully controlled laboratory conditions. Because of its economic importance, and because a carefully controlled procedure was already in operation, the codling moth larva, *Carpocapsa pomonella* L., was chosen as the test insect. The insecticides tested were from commercial samples separated into different particle-size fractions by means of a centrifugal-air classifier. In this paper are reported the results of a laboratory investigation of the particle-size toxicity relationship of five insecticides, namely, lead arsenate (acid), calcium arsenate, Paris green, cryolite (synthetic) and phenothiazine.

Experimental Procedure.—With the exception of lead arsenate each insecticide was separated into six or seven particle-size fractions. The finest, the coarsest and a medium cut were used for the toxicity tests because by the discarding of some of the intervening fractions overlapping was reduced as much as possible. In the case of lead arsenate, the fine fraction consisted of a very fine commercial sample and the coarse fraction was prepared from a portion of this by crystallization from dilute nitric acid.

The particle-size distribution in each fraction was determined by sedimentation analysis, the apparatus and method described by Goodhue & Smith (1936) being used. With phenothiazine it was necessary to use water as the sedimentation medium, because dilute alcohol, which is ordinarily used, exerted some solvent action. The approximate size of each fraction was checked by observation under the microscope.

In the tables the "mid-size" is included as a means of readily comparing the approximate average size of each fraction. The "mid-size" is that size which divides each fraction into two equal parts by weight.

The comparative size of the "mid-size" particles of each fraction is given in fig. 1. In this connection it is worthy of note that all these particles are in reality small. For example, the largest, those of phenothiazine, with a diameter of 45 microns, would pass through a sieve of about 325 mesh.

A chemical analysis was made of each fraction to determine its chemical composition. Also, the quantity of spray deposited on the apple plugs used in the toxicological tests was ascertained by chemical methods.

The toxicity tests were made in accordance with the apple-plug method, under laboratory conditions (Siegler & Munger 1933; Siegler, Munger and Gahan 1934). For all materials except phenothiazine five replicates of 100 or more apple plugs each were employed for each fraction. With the phenothiazine 730 and 748 plugs were used for the coarse and fine fractions, respectively, and 308 for the medium fraction. One worm was used with each plug. Each toxicity test was made at a dosage of 4 pounds of the insecticide to 100 gallons of the carrier. Except for phenothia-

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zine, the carrier was 20 per cent ethyl alcohol (by volume in water), which has been found to give good wetting and an even distribution. Because of the solvent power of dilute alcohol for phenothiazine, a soap solution made from 1 pound of neutral fish-oil soap in 100 gallons of water was employed as the carrier for this material.

LEAD ARSENATE.—The data pertaining to this compound will be found in table 1. As will be noted therein, the chemical composition of the two fractions was practically identical, and about the same quantity of each fraction was applied. The toxicological tests show that the coarse fraction was slightly more effective in killing the larva than was the fine fraction. This difference, although not great, was shown by a standard analysis of variance to be highly significant. Generally it has been claimed that for an insect as small as the codling moth larva smaller particles of lead arsenate give better control than larger particles.

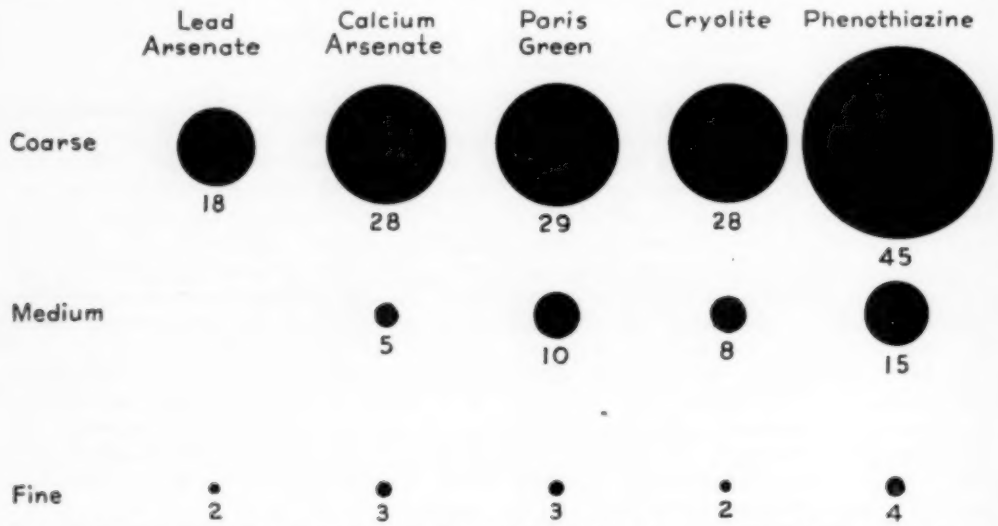

FIG. 1.—Comparative size of "mid-size" particles. The figures show the approximate diameter in microns.

Table 1.—Toxicity of coarse and fine fractions of lead arsenate to the codling moth larva and physical and chemical data on the fractions.

	Fractions	
TOXICOLOGICAL DATA	*Coarse*	*Fine*
Per cent wormy	18	28
Per cent stung	21	18
Per cent clean	61	54
Spray load on plugs, mmg./sq. cm.	31.5	32.5
PHYSICAL DATA (Size of Particles)		
Mid-size (diameter in microns)	18	less than 2
Proportion having following diameters, in microns:	*Per cent by weight*	
Larger than 30	9	—
Between 30 and 20	33	—
Larger than 20	(42)*	5
Between 20 and 10	32	4
Between 10 and 6	15	5
Smaller than 6	11	(86)*
Between 6 and 4	—	7
Between 4 and 2	—	10
Smaller than 2	—	69
CHEMICAL DATA	*Per cent by weight*	
Total arsenic oxide	32.5	31.4

* Parentheses indicate summation of some of the fractions.

CALCIUM ARSENATE.—The results of the study of this compound are given in table 2. The quantities of the fine, medium and coarse fractions of calcium arsenate applied to the apple plugs were about equal, but the fractions were dissimilar in chemical composition. The molecular ratios (arsenically combined CaO/total As_2O_5) for the coarse, medium and fine materials were 2.92, 3.20 and 3.47, respectively. The total arsenic oxide (As_2O_5) increased from fine to medium and from medium to coarse and the water-soluble arsenic increased in the same order. Since commercial calcium arsenate is a heterogeneous substance, chemical fractionation cannot be avoided in a particle-size fraction (Goodhue & Cassil 1938).

In the toxicity tests it was found that the medium fraction gave a lower percentage of wormy plugs than the fine or the coarse fraction. An analysis of variance showed this difference to be highly significant. This difference, however, may have been due to a difference in chemical composition rather than in particle size alone. It will be noted that the last two fractions permitted the same percentage of survivals in spite of the fact that the coarse fraction contained much more arsenic oxide and water-soluble arsenic. Because of the non-uniformity in the chemical composition of the calcium arsenate fractions, conclusions on the toxicity-particle size relationship cannot be drawn.

PARIS GREEN.—As shown in table 3, the total arsenious oxide was about the same in all fractions of Paris green, but the water-soluble arsenic was somewhat greater in the fine than in the medium and coarse fractions owing to a higher rate of solution during the period arbitrarily specified in the A.O.A.C. method for soluble arsenic. The load of applied insecticide increased slightly from fine to medium and from medium to coarse. As judged by the per cent of wormy plugs, the fine and coarse fractions gave similar control and medium fraction was somewhat more effective. An analysis of variance showed this difference to be highly significant.

CRYOLITE (SYNTHETIC).—The results obtained with this compound are presented in table 4. The chemical composition of the fractions of cryolite was about the same and the spray load per apple plug did not vary to any considerable degree. The medium fraction gave a slightly smaller percentage of wormy plugs than either the fine or the coarse fraction and, as determined by analysis of variance, the difference is highly significant.

PHENOTHIAZINE.—As will be noted in table 5, the chemical analysis of the fine, medium and coarse fractions of phenothiazine showed them to be nearly uniform in composition. The spray load of

Table 2.—Toxicity of coarse, medium and fine fractions of calcium arsenate to the codling moth larva, and physical and chemical data on the fractions.

	Fractions		
TOXICOLOGICAL DATA	*Coarse*	*Medium*	*Fine*
Per cent wormy	34	20	34
Per cent stung	23	28	26
Per cent clean	43	52	40
Spray load on plugs, mmg./sq. cm.	39.2	39.9	37.8
PHYSICAL DATA (Size of Particles)			
Mid-size (diameter in microns)	28	4.5	3
Proportion having following diameters, in microns:	*Per cent by weight*		
Larger than 50	11	—	—
Between 50 and 40	17	—	—
Between 40 and 30	16	—	—
Between 30 and 20	24	—	—
Between 20 and 10	25	—	—
Larger than 15	—	11	—
Larger than 10	(93)*	(23)*	10
Between 15 and 10	—	12	—
Smaller than 10	7	(77)*	(90)*
Between 10 and 5	—	20	14
Between 5 and 4	—	13	—
Between 4 and 3	—	15	—
Between 5 and 3	—	(28)*	28
Between 3 and 2	—	12	20
Smaller than 2	—	17	28
CHEMICAL DATA	*Per cent by weight*		
Total calcium oxide	39.3	45.8	50.5
Free calcium oxide	2.1	8.8	17.6
Calcium carbonate	4.8	13.8	12.9
Arsenically combined calcium oxide	34.5	29.0	25.7
Total arsenic oxide	48.4	37.2	30.3
Water-soluble arsenic	18.8	9.7	3.0

* Parentheses indicate summation of some of the fractions.

Table 3.—Toxicity of coarse, medium and fine fractions of Paris green to the codling moth larva, and physical and chemical data on the fractions.

	Fractions		
TOXICOLOGICAL DATA	*Coarse*	*Medium*	*Fine*
Per cent wormy	12	4	12
Per cent stung	21	18	20
Per cent clean	67	78	68
Spray load on plugs, mmg./sq. cm.	41.8	39	36.5
PHYSICAL DATA (Size of Particles)			
Mid-size (diameter in microns)	29	10	less than 2.8
Proportion having following diameters, in microns	*Per cent by weight*		
Between 60 and 40	10.0	—	—
Between 40 and 30	33.0	—	—
Between 30 and 20	42.0	4.5	—
Between 20 and 15	4.5	14.0	2
Between 15 and 10	4.0	28.0	1
Between 10 and 6	1.5	32.0	8
Between 6 and 2.8	5.0	12.0	32
Smaller than 2.8	—	9.5	57
CHEMICAL DATA	*Per cent by weight*		
Total arsenious oxide	57.03	57.58	58.67
Total cupric oxide	30.53	30.60	30.53
Water-soluble arsenic	1.32	1.88	4.24

Table 4.—Toxicity of coarse, medium and fine fractions of synthetic cryolite to the codling moth larva, and physical and chemical data on the fractions.

	Fractions		
Toxicological Data	*Coarse*	*Medium*	*Fine*
Per cent wormy	11	5	11
Per cent stung	19	25	27
Per cent clean	70	70	62
Spray load on plugs, mmg./sq. cm.	48.3	51.3	44.5
Physical Data (Size of Particles)			
Mid-size (diameter in microns)	28	8	2
Proportion having following diameters, in microns:	*Per cent by weight*		
Larger than 60	29	—	—
Between 60 and 40	8	—	—
Between 40 and 30	11	—	—
Larger than 30	(48)*	—	—
Between 30 and 25	10	—	—
Between 25 and 20	12	—	—
Between 30 and 20	(22)*	—	—
Larger than 20	(70)*	6	—
Between 20 and 15	17	—	—
Smaller than 15	13	—	—
Between 20 and 10	—	26	—
Larger than 10	—	—	8
Between 10 and 7	—	40	—
Between 7 and 5	—	16	—
Between 10 and 5	—	—	8
Smaller than 5	—	12	—
Between 5 and 4	—	—	4
Between 4 and 3	—	—	8
Between 3 and 2	—	—	28
Smaller than 2	—	—	44
Chemical Data	*Per cent by weight*		
Total fluorine	52.2	53.3	55.1

* Parentheses indicate summation of some of the fractions.

the fine and medium fractions was about the same, as was also the larval control, but a striking difference in toxicity is indicated by the lack of effectiveness of the coarse fraction, despite the fact that the spray deposit was considerably heavier than it was with the fine and medium fractions. As computed from an analysis of variance, the difference in toxicity between the coarse fraction and either the medium or the fine fraction is highly significant. The particles in the coarse fraction of phenothiazine were about twice as large as in the coarse fractions of any of the other insecticides, and this may account for the abrupt drop in toxicity. Other coarse insecticide fractions should be tested to obtain a true comparison of their effectiveness.

DISCUSSION.—In view of the data presented in this paper, it appears that some rather generally accepted ideas are not corroborated by experimental findings in so far as they apply to the codling moth larva. For example, so-called colloidal lead arsenate has been claimed to be as effective at a much lower dosage as ordinary lead arsenate at standard dosage. A fine Paris green, now on the market, is also believed by some to be more effective than the usual commercial product. The results obtained here indicate that a lead arsenate somewhat coarser than that ordinarily available is slightly more effective, as are also the medium samples of Paris green and cryolite. It is, of course, obvious that particles too large to be ingested by the insect would be of no value, but somewhere below this critical size there appears to be a range which is the most effective under laboratory conditions. This need not be the finest possible material nor need it be the same for every insecticide. From the data obtained thus

Table 5.—Toxicity of coarse, medium and fine fractions of phenothiazine to the codling moth larva, and physical and chemical data on the fractions.

	Fractions		
Toxicological Data	*Coarse*	*Medium*	*Fine*
Per cent wormy	62	9	10
Per cent stung	2	1	4
Per cent clean	36	90	86
Spray load on plugs, mmg./sq. cm.	64	45	43
Physical Data (Size of Particles)			
Mid-size (diameter in microns)	45	15	4
Proportion having following diameters, in microns:	*Per cent by weight*		
Larger than 60	30	—	—
Between 60 and 50	15	—	—
Between 50 and 40	12	—	—
Between 40 and 30	13	—	—
Smaller than 30	30	(over 70)	—
Larger than 20	—	40	—
Between 20 and 15	—	10	—
Between 15 and 10	—	17	—
Smaller than 10	—	33	(over 67)
Larger than 5	—	—	33
Between 5 and 4	—	—	17
Between 4 and 3	—	—	12
Smaller than 3	—	—	38
Chemical Data			
Insoluble in petroleum ether, per cent by weight	98.2	97.8	98.8
Melting point of soluble parts, degrees C.	180	180	180
Red color test on original, per cent	103	100	97

far it seems that the optimum particle size range should be carefully determined for every stomach poison used to combat insects of economic importance.

In the case of phenothiazine, where it was possible to separate a coarser fraction than from the other commercial insecticides, the results were distinctly different. The fine and medium fractions gave good control whereas the coarse fraction was decidedly less effective.

SUMMARY.—The effect of particle size on the toxicity of five insecticides to the codling moth larva is reported in this paper. Three fractions each, graded as to particle size into fine, medium and coarse, of calcium arsenate, Paris green, cryolite (synthetic) and phenothiazine, and two fractions of acid lead arsenate were tested in replicated series. Except for phenothiazine, no great difference in toxicity of the different fractions was obtained, but the medium fraction was generally slightly superior. In the case of lead arsenate, the coarse fraction was somewhat more effective than the fine (no medium fraction was prepared). The coarse fraction of phenothiazine was much less toxic than was the fine or the medium fraction.—11-18-38.

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The Hurricane and the Newer Shade Tree Insect Problems

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The hurricane of last September was a major catastrophe in New England. The storm wave on the coast exacted a heavy tribute in life and property values, and the raging waters of swollen streams brought death and destruction to many in inland localities. The terrific wind, varying greatly in its intensity, overthrew or wrecked a million or more large shade trees and wrought extensive damage in forested areas.

STORM DAMAGE TO SHADE TREES.—The morning of September 22 revealed an unparalleled situation in that section of the country. Highways were blocked, telephone, telegraph and electric power lines were down and for some days there was a nearly general paralysis of these services. There was a similar storm covering about the same territory in 1815, presumably accompanied by the destruction of many trees. The situation then was not so serious as last September since in those early days the community and the individual family was more nearly self-sufficient, at least for short periods. The difference is suggested by the fact that in 1815 Worcester, Mass., had a population of 2,500 to 2,900, whereas the latest census places the number of inhabitants at nearly 200,000. It should be noted that this disruption of communications and services last September was caused to a very considerable extent by fallen or wrecked shade trees and, although there were great losses in forested areas, many of the acute difficulties resulted from fallen shade trees. This paper is concerned primarily with insect problems having a somewhat direct relation to the widespread loss of shade trees outlined above.

A general survey of the storm swept area forces the conclusion that the greatest shade tree damage was on village greens or commons, in parks and parklike areas on private grounds, and on city or village streets. It was also limited to a very considerable extent to large trees 50 years of age or older. It was noticeable that similar trees in the open country

along roadsides or on lawns escaped damage to a perceptibly greater extent. It is believed that a part of this exemption is due to better growing conditions and relative freedom from insect attack in the case of the trees in the open country.

DEFOLIATION EFFECTS.—City and village trees during the past 40 years have suffered greatly from such leaf eating pests as the gypsy moth, *Porthetria dispar* (L)., cankerworms, *Alsophila pometaria* (Harr.) and *Paleacrita vernata* (Peck), the elm leaf beetle, *Galerucella xanthomelaena* (Schr.) It will be recalled that spraying to protect shade trees from such pests was in its infancy in the 1890's and that many city and village trees have suffered greatly from elm leaf beetle attack over much of the past 40 years. It is well known that repeated defoliation weakens trees and results in dying branches and the eventual death of the tree. The dying branches, unless there is systematic pruning and protection of the cut surfaces with a wound dressing, means early invasion by wood rots. Too frequently such care is wanting. There is a significance in the fact that 90 per cent of the seriously damaged trees had been invaded and appreciably weakened by wood rots. Furthermore, the repeated destruction of the leaves weakens the trees and means a poor root development with a consequent inability of the trees to resist winds of hurricane force. It is our opinion that repeated attacks in earlier years by elm leaf beetle in cities and villages was an important contributing factor in the destruction of many magnificent shade trees last September.

The weakening effects of repeated defoliations by no means end here. They produce conditions in the early stages which are favorable to invasion by cambium or bark borers, such as the two-lined chestnut borer, *Agrilus bilineatus* (Web.), the hickory bark beetle, *Scolytus quadrispinosus* Say, the bronzed birch borer, *Agrilus anxius* Gory, and the spotted hemlock borer, *Melanophila fulvoguttata* (Harr.), all species which multiply greatly and hasten the killing of host trees weakened by one cause or another. A weakened condition is also favorable to a great multiplication of the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, the principal carrier in America of the Dutch Elm disease. Available evidence indicates that *Scolytus sulcatus* LeC., a species which develops in apple, plum and elm may also carry the Dutch elm disease.

TREES IN CEMETERIES.—Sweeping to almost complete destruction of trees in many cemeteries was noted. This destruction appeared to be limited mostly to pine and Norway spruce, though a number of partly cleared hardwood areas were badly damaged. The pine and spruce destruction has no marked relation to insect work and the damage to the hardwood areas was due in large measure to deficient root development.

WEAK TREES INVADED BY BORERS.—It may be well to note at this point that trees or parts of trees weakened by this storm offer favorable conditions to an increase of one or more of the cambium or bark borers. Hanging branches offer favorable conditions for the European elm bark beetle, limbs which have been twisted or weakened are attractive to the two-lined chestnut borer and the hickory bark beetle, and many leaning or wrecked trees may have had their roots torn to such an extent that the entire tree may be weakened so greatly as to facilitate invasion by one or more of these borers. The present situation makes it extremely desirable that so far as possible all weak elm wood, trees or parts of trees, be cut and burned or at least barked before April 1, in order to reduce the numbers of the elm bark beetle, principal carrier of the Dutch elm disease. Such measures are especially important in areas where the disease is known to occur and are advisable in other sections.

Hurricanes in the south Atlantic states are usually followed by a great increase in the numbers of several borers, particularly the bark beetles of the genus *Dendroctonus* which commonly work under the bark in southern pines and kill large numbers of trees. A similar development may be expected in the pines of New England through increase in the numbers of related bark beetles. *Dendroctonus* and *Ips*, and there are also likely to be great numbers of long-horned borers, *Monochamus*, which produce the large grubs known as "sawyers" so commonly found in pine logs. The weakening from storm injury mentioned above may be expected to pro-

duce conditions analogous to fire damage and there may be considerable invasion of sugar maple, flowering dogwoods, and other hard woods by flat-headed borers, *Chrysobothris* and allies, which ordinarily attack these trees in great numbers when they have been weakened by fire.

STUMP DISPOSAL.—Treatment of elm stumps, so as to prevent the later development of bark beetles, is especially important in areas where the Dutch elm disease has become established. Pine stumps and logs are favorable to the development of weevils, and small ornamental pines growing near such material may be attacked later by the pales weevil, *Hylobius pales* Boh. the pine trunk weevil, *Pissodes approximatus* Hopk., and possibly by the pine root weevil, *Hylobius radicis* Buchanan.

BORERS AND WOOD ROTS.—There is need of full recognition of the part played by larger wood borers such as the sugar maple borer, *Glycobius speciosus* (Say), the locust borer, *Cyllene robiniae* (Forst.), the leopard moth, *Zeuzera pyrina* (L)., the carpenter worm, *Prionoxystus robiniae* (Peck), an insect which breeds commonly in oak and sugar maple, the callous borer, *Conopia acerni* (Clem.), a somewhat common insect in soft maple, and the ash and lilac borers, *Podesesia fraxini* (Lugger) and *P. syringae* (Harr.), all of which presumably have been important in producing conditions favorable to invasion by wood rots and have thus contributed to more extensive storm damage. The weakened branches and trunks resulting from the recent hurricane are also likely to favor a considerable increase in the numbers of these pests.

SALT INJURY AND WEEVIL ATTACK.—There is another type of storm damage which deserves at least mention. The high wind carried salt spray to a distance of 50 miles or so from the coast, producing a sudden change from the normal brilliant foliage of late September to a lifeless, gray leafage. This was probably not serious in the case of the broadleaved trees, especially as the high winds were followed by considerable rain. Enough salt was deposited upon white pines and pitch pines to burn the needles severely, and many of the white pines have shed their foliage and will be in a weakened condition for a year or two. This means a likelihood of weevil invasion by such insects as the pine trunk weevil and the pine root weevil, *Pissodes approximatus* and *Hylobius radicis*, respectively.

INSECT CONTROL FOR STURDIER TREES.—The entomologist has been advocating spraying of shade trees largely because this keeps the trees in an attractive and healthy condition. The sweeping force of the storm and the consequent wreckage justifies the belief that protection of shade trees from various insect pests makes possible the growing of sturdier and more storm resistant trees. Weak trees, as mentioned above, menace life and limb, as well as what we believe to be essential comforts or conveniences under present day conditions, and we have in these other cogent reasons for urging better control measures against insects attacking both our shade and ornamental trees.

PROBABILITY OF GREATER INSECT DAMAGE.—The considerable reduction in the number of trees on streets and commons means in the case of the elm leaf beetle more insects to attack the remaining trees another season. This is also likely to be the case in areas where canker worms and Japanese beetles, *Popillia japonica* Newm., are numerous. The shade tree work of 1939 should be planned with the possibility in mind of increased damage by a number of leaf eaters and possibly more serious trouble from bark beetles and various other borers attacking weakened trees.

WEAK TREES A NATIONAL PROBLEM.—The hurricane, although it caused enormous losses, has focused general attention on the fact that there are many weakened shade trees. It should not be supposed for a minute that the hurricane blew down or wrecked all the trees in the storm swept area that were in poor condition. It took out a relatively small proportion. It is equally important to recognize the fact that weakened shade trees are by no means confined to the northeastern United States. The tale of the hurricane outlined briefly above may be duplicated in other sections of the country, the extent of the disaster depending in large measure upon the size of the area covered by the storm.—11-17-38.

Dormant Spray Mixtures on Conifers*

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The question of plant tolerance to spray and dust mixtures is so intimately associated with the insect control program that the possibility of injury cannot be overlooked. In experiments with insecticides one of the first questions that arises is whether or not a certain material can be applied without injury to the plant. For the past several years the senior author has been investigating dormant and summer spray mixtures as they relate to nursery stock, ornamental plants and shade trees, while the junior author has been primarily concerned with the use of similar materials on fruit trees. The present paper deals with some findings regarding plant tolerance of conifers to dormant and summer sprays and the toxicity of these materials to certain insects.

Experiments on Conifers Previous to 1938.—For the past 10 years experiments have been conducted (Gambrell 1934) on the control of the eastern spruce gall aphid, *Adelges abietis* (L.), and other nursery insect pests. In many of these tests on conifers various types and dilutions of coal tar oils, petroleum oil, lime sulfur and other spray materials have been investigated. It has been interesting to observe the effect of oils of different types, dilutions and viscosities on spruces during this period. As one might suspect, the degree and amount of injury frequently varied during different seasons even when the same dilution of a given oil mixture was used. For instance, a dormant spray containing 1 per cent of *Junior Red Engine* oil (viscosity 215 sec. at 100 degrees F.) was emulsified and used on Norway spruce with relative safeness during most seasons, but occasionally definite foliage injury resulted from the use of this mixture. A similar concentration of a lower viscosity oil (100 sec. at 100 degrees F.), commonly known as *Diamond Paraffin Oil*, was apparently less toxic to the foliage and afforded satisfactory control of the spruce gall aphid. Even the use of this mixture was occasionally attended with some injury. Coal tar oil sprays at dilutions of from 1 to 4 per cent of actual oil were relatively non-toxic to spruce foliage with but one exception, at 4 per cent concentration, and were effective in controlling the insect. Lime sulfur at a dilution of 1–8 was also perfectly safe and likewise afforded excellent control. This latter mixture has also been used at a similar dilution with safety on Pfitzer and Savin junipers for the control of juniper scale. Limited experiments with lime sulfur diluted 1–40 and 1–8 have been used on Savin juniper in the summer with no apparent injury. The above findings relative to the use of the different mixtures on spruce are in general agreement with those of Herrick & Tanaka (1926) and Britton (1928).

During 1936 and 1937 various insecticides were tested as summer and dormant treatments for the control of spruce needle miners, *Olethreutes abietana* Fern. and *Recurvaria piceaella* Kf. on Norway and Koster blue spruce in nursery plantings. In 1936 *Orthol-K* oil (1 gallon to 100) was used alone and in combination with lead arsenate, calcium arsenate and nicotine sulfate on Koster blue spruce in nurseries. Other tests included arsenicals in combination with nicotine sulfate, nicotine sulfate and *Gardinol*, and arsenical dusts. These sprays were applied June 11, June 19 and July 2, respectively. The weather was particularly hot and dry throughout most of the summer, and the writers feel that adverse weather conditions were conducive to excessive spray injury. The results with these materials, from the standpoint of plant toxicity, are briefly as follows: (1) Foliage injury was serious on all trees sprayed with either oil alone or in combination with lead arsenate, calcium arsenate or nicotine sulfate. (2) Injury was much more severe on the trees sprayed June 11 than on those treated at a later date; in fact, most of the trees sprayed on June 11 were entirely killed. While injury was severe on trees sprayed June 19 and July 2, it was more noticeable on the lower half of the trees and much worse on the south and west exposures. In spite of the extremely hot, dry weather, the untreated trees failed to show similar injury. (3) Trees sprayed with either calcium arsenate or lead arse-

* Approved by the Director of the New York State Agricultural Experiment Station, Geneva, for publication as Journal Paper No. 304, December 17, 1938.

nate at the rate of 4 pounds to 100 gallons, either alone or in combination with nicotine sulfate 1–800, did not show any apparent foliage injury. These results indicate that the oil alone, or when combined with these materials, was mainly responsible for the injury incurred. The results of these treatments on the control of spruce needle miners, although certain mixtures showed promise, will not be discussed in detail.

Dormant treatments were made May 4, 1937, on Norway spruce for the control of *Recurvaria piceaella* Kf. In these tests *Orthol-K* oil (1 gallon to 100) was used with 1 quart of nicotine sulfate and 4 pounds of lead arsenate. A mixture containing *Orthol-K* oil and lead arsenate was used at the concentrations just mentioned. Lead arsenate with nicotine sulfate was also used in the same proportions without oil. None of these mixtures caused any foliage injury. Careful, but limited, counts showed the following per cent kill of the overwintering larvae: Lead arsenate plus nicotine sulfate, 88; oil plus lead arsenate, 90; oil plus lead arsenate plus nicotine sulfate, 90.

During the past three years various dormant treatments have been tested for the control of the pine needle scale, *Chionaspis pinifoliae* (Fitch), on Red and Scotch pines (Gambrell 1938). As regards toxicity to the foliage the results may be briefly stated as follows: (1) Coal tar oils at dilutions of 1, 2, 3 and 4 per cent of actual oil have not caused noticeable injury to either buds or foliage, and mixtures containing 2 per cent or more have afforded a high degree of control (93–96 per cent efficiency); (2) lubricating oil emulsions (viscosity of oil 100 sec. at 100 degrees F.) containing 2 and 4 per cent actual oil caused foliage injury and were not so effective in controlling pine needle scale as similar concentrations of coal tar oils; (3) miscible oils have varied both in effectiveness and safeness during different seasons, but in no case was the injury serious; (4) summer sprays containing 1 and 2 gallons of *Orthol-K* oil emulsion also afforded satisfactory control of the immature stages of the pine needle scale (97–100 per cent efficiency) without any apparent injury to the trees, which is in conformity with those reported by Richardson (1930) on white spruce, white pine and red pine; (5) DN-oil*—lubricating oil containing 4 per cent of dinitro-o-cyclohexylphenol—as dormant applications at 2 and 4 per cent concentrations afforded satisfactory control but were very toxic to the foliage. In tests conducted during the past two years a spray containing 1 per cent of DN-oil has afforded satisfactory control with much less injury than higher concentrations of this material.

EXPERIMENTS ON PINE NEEDLE SCALE IN 1938.—The tests carried out with dormant treatments in 1938 were mainly a continuation of those conducted during the past two seasons, except for some of the DN-oil mixtures, *Elgetol*† (a salt of dinitro-cresylate and other ingredients) and lime sulfur. All of the spray mixtures indicated in table 1 were applied April 25 with a power sprayer. The per cent efficiency of these materials was determined by the same formula as that used by Hartzell & Moore (1937). In this series of tests the DN-oil mixtures and *Elgetol* were used at the same dilutions as in the plant tolerance tests indicated in table 2. Scotch and red pine, approximately 15 years old, were sprayed, and it is interesting to note that foliage injury was apparently more severe in many cases than that which occurred on 8- to 10-year old trees in the plant tolerance experiment. Trees sprayed with 3 per cent of DN-oils and of *Elgetol* were very seriously injured, and many buds and lateral branches were entirely killed, while others were seriously affected. Owing to the severe injury caused by the materials just mentioned, most, if not all, of the 1937 needles fell off early in the season; therefore no records of insect control were obtainable on these plats. It will be noted in table 1 that all of the treatments where data could be secured, with the exception of 1 per cent coal tar oil, gave excellent control. For the past three seasons coal tar oil at concentrations of 2 per cent or more of actual oil have afforded excellent control without causing any foliage injury; also 1 per cent of DN-oil (4 per cent DN) gave satisfactory control during 1936 and 1937 with only slight foliage injury. While 1 per cent of the same DN-oil has proved effective in controlling the pine needle scale, further tests are neces-

* Made by the Dow Chemical Company, Midland, Mich.
† Manufactured by Standard Chemical Products, Inc. Hoboken, N. J.

Table 1.—Dormant treatments for control of pine needle scale.

TREATMENT	DILUTION†	NUMBER OF OLD SCALES	NUMBER OF NEW SCALES	RATIO YOUNG TO OLD	PERCENTAGE DECREASE OF INFESTATION	PERCENTAGE* EFFICIENCY
Coal tar oil	1.2	366	304	0.8306	16.93	91.81
Coal tar oil	3.6	1064	25	0.0235	97.65	99.76
Sunoco	4.0	515	11	0.0213	97.86	99.79
Scalecide	5.0	582	18	0.0309	96.90	99.69
Lime sulfur	12.5	727	11	0.0151	98.48	99.85
DN-oil (4% DN)	1.0	276	2	0.0072	99.27	99.92
DN-oil (2% DN)	1.0	449	14	0.0311	96.88	99.69
Elgetol	1.0	153	2	0.0130	98.69	99.87
Check	—	131	1329	10.1450	—	—

* A ratio of 1 signifies 90.14 per cent efficiency.
† Gallons of material indicated per 100 gallons of spray.

sary to determine its safeness under a variety of conditions. In table 1 it will also be noted that a 1 per cent concentration of *Elgetol* caused serious foliage injury but gave satisfactory control. There is a possibility that, judged from their efficiency on pine needle scale and other insects, DN-oil and *Elgetol* may be used safely and efficiently at concentrations lower than 1 per cent on conifers and thereby minimize the danger of foliage injury. Lime sulfur diluted 1 to 8 proved safe and effective during 1938 for the control of pine needle scale.

EXPERIMENTS ON PLANT TOLERANCE OF CONIFERS IN 1938.—The satisfactory results obtained by Hartzell *et al.* (1937, 1938) with DN-oils on fruit insects during the past several years and with *Elgetol* in 1937 suggested the possibility of their use on insects affecting conifers. Before conducting extensive field tests on valuable trees with these newer materials it was felt essential that the tolerance of conifers to various concentrations of these and other materials be determined. The Experiment Station maintains a planting of coniferous trees for experimental purposes, and on these trees tests were made during the spring of 1938 in an effort to establish the tolerance of different species of conifers to various dormant sprays. While previous experience has indicated that coal tar oil and certain petroleum oils were relatively safe on conifers, these materials were included to serve as a basis of comparison with DN-oil and *Elgetol*.

Table 2.—Plant toxicity tests of dormant spray mixtures on conifers, 1938.

SPECIES OF TREE	TREATMENT AND OBSERVATIONS ON FOLIAGE INJURY					
	1 Per Cent DN-Oil* (4 per cent DN)	3 Per Cent DN-Oil (4 per cent DN)	1 Per Cent DN-Oil (2 per cent DN)	3 Per Cent DN-Oil (2 per cent DN)	1 Per Cent *Elgetol*	3 Per Cent *Elgetol*
Norway spruce	moderate	severe	moderate	severe	none	severe
White spruce	moderate	severe	moderate	severe	none	severe
Colorado spruce	moderate	severe	†	†	moderate	severe
Austrian pine	none	severe	slight	severe	slight	†
Chinese pine	slight	moderate	slight	moderate	slight	moderate
Jack pine	none	severe	none	moderate	slight	severe
Jeffrey pine	none	severe	moderate	severe	moderate	†
Mugho pine	none	moderate	none	moderate	slight	slight
Pitch pine	none	severe	severe	severe	moderate	severe
Red pine	slight	severe	moderate	severe	slight	moderate
Scotch pine	none	severe	slight	moderate	moderate	severe
Western yellow pine	slight	severe	slight	severe	slight	severe
White pine	none	moderate	slight	severe	moderate	severe
American arbor-vitae	none	severe	moderate	severe	slight	slight
Oriental arbor-vitae	slight	severe	slight	severe	slight	severe
Douglas fir	slight	severe	moderate	severe	slight	severe

* Per cent of oil or active ingredient.
† Material was not tested due to lack of sufficient trees.

Table 2 gives a partial list of materials and concentrations used and notes on plant tolerance. In addition, coal tar oil, *Scalecide*, *Dendrol*, *Diamond Paraffin Oil* and *Nursery Volck* were used at dilutions of 1 and 3 per cent of actual oil on the same species, with the following exceptions: Coal tar oil and *Scalecide* were not tested on jack pine, mugho pine, and Oriental arbor-vitae; *Dendrol* was not tested on jack pine and mugho pine. With the exception of 3 per cent *Dendrol*, which produced slight injury on Norway, white and Colorado spruce and of 3 per cent *Diamond Paraffin Oil*, which caused a similar effect on Norway spruce, no injury was observed from these treatments.

All materials were applied on April 15 and 16 with a power sprayer at from 300 to 400 pounds pressure and trees were sprayed very thoroughly. The trees used in these tests were set as two- and three-year transplants in 1931 and 1932. The following species were included in the test: *pine*—Austrian, Chinese, jack, Jeffrey, mugho, pitch, red, Scotch, western yellow, white; *spruce*—Colorado, Norway, white; *fir*—Douglas; *arbor-vitae*—oriental, American.

In the classification of the injury incurred, certain arbitrary standards were used, as indicated in table 2. According to this classification, "slight" refers to a small amount of browning on some of the needles, but is not necessarily considered sufficiently serious to preclude the use of sprays causing this degree of injury; "moderate" signifies a much more noticeable browning and possibly some shedding of foliage. The use of mixtures falling in this classification would be considered very questionable, but under some conditions their use may be warranted. "Severe," of course, signifies serious foliage injury, shedding of needles, retardation and stunting of new growth in certain instances, and the possible killing of some buds.

In the classification of the various groups of conifers with regard to susceptibility, the spruces appear to be the most sensitive, followed in order of decreased likelihood of injury by Douglas fir, arbor-vitae and pine. Within the three groups only slight or indiscernible differences in foliage injury were noted between some species, while between other species the variations were more striking. For convenience, the species within the various groups may be roughly classified as follows: *pines*—red, Scotch, pitch, jack, Chinese, white, Jeffrey, western yellow, Austrian and mugho; *spruce*—white, Colorado and Norway; *arbor-vitae*—oriental and American.

From these tests it appears that DN-oil (2 or 4 per cent DN) and *Elgetol* at concentrations greater than 1 gallon in 100 gallons of spray mixture are likely to be attended with serious injury on evergreen conifers. There is a possibility that even 1 gallon of DN-oil or of *Elgetol* per 100 gallons of spray mixture may prove injurious under certain conditions such as heavy drenching sprays, adverse weather or low tree vigor. One and 3 per cent concentrations were used because previous experiments had shown these amounts to be the lower and upper limits of concentration necessary for the control of certain fruit insects. Lack of a sufficient number of trees prevented use of all the mixtures on certain species as well as additional tests at other concentrations on the other kinds. The trees were not sufficiently infested to secure data on insect control.—11-17-38.

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Control of Whiteflies on Gardenias

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In February, 1938, whiteflies (*Aleyrodidae*) became abundant on a tropical hibiscus plant that was in an 8-inch flower pot in the Virginia Truck Experiment Station greenhouse. An effort was made to control this pest by dipping the plant in a solution containing 1 per cent of a 40 per cent nicotine sulfate, 1 per cent liquid soap and 98 per cent water, but only the adult whiteflies that were caught in the dip were killed. Later the plant was dipped in a 1 per cent solution of *lethane 440*, an aliphatic thiocyanate, and again no control of the immature stages was obtained.

By March many of the leaves of this hibiscus plant were heavily infested with all stages of the whitefly and some of the leaves were turning yellow. At this time one-half of the plant was dipped for 30 seconds in a solution containing 1 per cent of a 60 per cent *Stantex Dispersing Oil* and 40 per cent of a derris extract in camphor sassafras base oil containing 5 grams of rotenone in 100 cubic centimeters, 1 per cent liquid *Red "A" Soap* and 98 per cent water. *Stantex Dispersing Oil* is a mineral oil containing a small percentage of oleic acid and a certain spreader. The liquid *Red "A" Soap* used in these tests contains 40 per cent dry soap. The other half of the plant was dipped for a similar length of time in a 1 per cent mixture of 80 per cent *Pyrolene M. P.*, and 20 per cent of the derris extract described above. *Pyrolene M. P.*, is a sodium salt of a synthetic wax prepared from a vegetable base.

Both treatments gave 100 per cent control of all stages except for a few adult whitefies that escaped before the plant was submerged. The plant suffered no apparent ill effects from the treatments and within a few weeks the dead bodies and cast skins of the whiteflies came off of the leaves, and the plant was restored to a normal thrifty condition.

ABUNDANCE ON GARDENIAS.—The citrus whitefly, *Dialeurodes citri* Ashm. (determination by Miss Louise M. Russell) has been a serious pest of gardenias in the Norfolk area for several years. The infestation was especially severe in 1938, and the Experiment Station received many calls in regard to whitefly control from April until cold weather came in the fall. With this abundance of whiteflies and in view of the striking results obtained with the oil-rotenone dips in the control of whiteflies on the hibiscus plant as described above, several tests were made with these materials in comparison with several other materials recommended for whitefly control.

TEST 1 ON GARDENIA.—In the first week of May whiteflies were satisfactorily controlled on two gardenia bushes in Norfolk. One bush was sprayed with *Elgeté* (1-33) and the other bush was sprayed with a 1 per cent solution of *Stantex R* to which *Red "A" Soap* was added at the rate of 1 to 200. *Elgeté* is an emulsified peanut oil and *Stantex R* is a mixture containing 80 per cent *Stantex Dispersing Oil* and 20 per cent of the derris extract in the camphor sassafras base oil. No definite counts were made of the different stages of the whiteflies that were killed, but it was observed that some of the adult flies flew away before the spray hit them. The plants were examined a week later and no living nymphs were observed, and only a few adults had returned to the bushes. It seemed that more live adults returned to the bush treated with *Stantex R* than to that treated with *Elgeté*, which may have been due to the presence of an oily residue remaining on the *Elgeté* treated plant. In June these two bushes were in a healthy growing condition and the whiteflies were still scarce, but by October 12, the bushes had become moderately reinfested.

TEST 2 ON GARDENIA.—On September 10 another test was made on gardenias in Norfolk. The materials were applied with a *Cali-Spray Super Mist* hand sprayer that maintained a pressure of from 100 to 150 pounds. Special effort was made to spray the under sides of the leaves as that was where most of the whiteflies were located. On September 19 counts were made on the number of living and dead nymphs on three leaves from each treatment. The materials used and the proportions at which they were used and the per cent control of the whitefly nymphs are given in table 1. The *Stantex*

Spreader Soap used in this test is a mixture containing 50 per cent potash soap and 50 per cent *Pyrolene M. P.* The *Volk* used in these tests was *Ortho Brand Garden Volk* consisting of 31.76 per cent heavy grade petroleum oil, 2.07 per cent nicotine alkaloid, 11.5 per cent soap and 54.67 per cent inert ingredients. The fish oil is obtained from menhaden fish and has a specific gravity of about .91. While the leaves examined on September 19 were under observation in the laboratory from September 17 to 22, 18 adult flies emerged from the untreated leaves and no flies emerged from the treated leaves. It was also noted that there were very few unhatched eggs, more newly hatched nymphs and more empty pupal cases on the untreated leaves than on the treated leaves.

Table 1.—Results of spraying gardenias for the control of whiteflies. Treatments made September 10 and control counts made September 19.

Materials Used	Proportions	Per Cent Control of Nymphs
Stantex R *Stantex Spreader Soap*	1/100 1/200	98.8*
Stantex R *Stantex Spreader Soap*	1/200 1/200	92.7‡
Stantex R *Stantex Spreader Soap*	1/400 1/200	90.7‡
Elgeté	1/25	94.4†
Elgeté	1/50	95.1†
Elgeté	1/100	94.0‡
Fish Oil *Red "A" Soap*	1/15 1/200	98.8*
Volk	1/25	91.4†
Check	—	0.0‡

* No newly hatched nymphs crawling around.
† A few newly hatched nymphs crawling around.
‡ Many newly hatched nymphs crawling around.

FOLIAGE INJURY.—In the test described above it was observed that all of the treatments caused a few of the heavily infested leaves to turn yellow and drop to the ground within a week or so after treatment. The gardenia plants treated September 10, as indicated in table 1, received a second treatment on October 10. At this time the bushes were thoroughly sprayed with the fish oil (1/15) and *Red "A" Soap* (1/200) mixture in an effort to control the whiteflies on the portion of the bushes not treated on September 10. As a result, within 10 days practically all of the leaves fell from the parts of the bushes that had been treated previously, while only a few of the leaves dropped from the parts of the bushes that had been left as untreated checks. This indicates that two applications, the latter being fish oil, within such a short

Table 2.—Results of spraying gardenias for the control of whiteflies. Treatments made October 6 and control counts made October 14.

Materials Used	Proportions	Number of Live Nymphs on Three Leaves		Per Cent Control
		Oct. 6	Oct. 14	
Stantex R *Red "A" Soap*	1/50 1/200	230	0	100
Fish Oil *Red "A" Soap*	1/15 1/200	835	0	100
Stantex R *Red "A" Soap*	1/100 1/200	296	2	99
Elgeté	1/25	203	8	96
Elgeté	1/50	271	77	72
Volk	1/25	226	107	53
Elgeté	1/100	427	291	32
Check	—	276	362	−31

interval of time are apt to injure the foliage seriously. In several later tests the fish oil (1/15) treated plants had a tendency to drop more leaves than did any of the other treated plants.

TEST 3 ON GARDENIAS.—On October 6 a test was made on gardenias in Fox Hall near the Experiment Station. In this test three leaves were tagged for each treatment and the untreated check. The number of live whitefly nymphs was counted on each of these leaves before treatment. A small, one-pint atomizer hand sprayer was used in this test and the under side of each tagged leaf was sprayed individually. Counts of the live nymphs were made again on these same leaves on October 14. The materials used and the results obtained are given in table 2. Again the *Stantex R* 1/50 and 1/100, the fish oil 1/15 and the *Elgeté* 1/25 gave good control while the *Elgeté* 1/50 and 1/100, and the *Volk* were not as effective. It should be noted that the whiteflies were quite active at this time as shown by the 31 per cent increase of nymphs on the untreated leaves.

TEST 4 ON GARDENIAS.—On November 3 the test made on October 6 was repeated with the addition of weaker dilutions of fish oil. The materials and proportions at which they were used, the number of live nymphs and the per cent of control are given in table 3. It may be noted that the fish oil plus soap treatment was very efficient down to and including the 4 per cent mixture. Also, the 2 per cent mixture was very effective except on one leaf that apparently was not well sprayed, while there was a sudden decline in the effectiveness of the fish oil between strengths of 2 and 1 per cent. The *Stantex R* and *Elgeté* treatments gave about the same results as in the previous tests while for some unknown reason *Volk* dropped considerably in effectiveness. It is interesting to note that there was practically no increase in the nymph population on the untreated leaves at this time; however, the number of newly hatched nymphs crawling around were not included in the number of live nymphs given in table 3. Newly hatched nymphs were observed crawling only on the un-

Table 3.—Results of spraying gardenias for the control of whiteflies. Treatments made November 3 and control counts made November 10.

MATERIALS USED	PROPORTIONS	NUMBER OF LIVE NYMPHS ON THREE LEAVES		PER CENT CONTROL
		NOV. 3	NOV. 10	
Stantex R *Red "A" Soap*	1/50 1/200	452	0	100
Stantex R *Red "A" Soap*	1/100 1/200	521	0	100
Fish Oil *Red "A" Soap*	1/15 1/200	632	0	100
Fish Oil *Red "A" Soap*	1/25 1/200	737	0	100
Elgeté	1/25	657	6	99
Fish Oil *Red "A" Soap*	1/50 1/200	847	56*	93
Elgeté	1/50	218	80	63
Fish Oil *Red "A" Soap*	1/100 1/200	343	259	43
Volk	1/25	357	301	13
Check	—	372	387	−4

* 50 live nymphs were found on one leaf that apparently was not sprayed well.

treated and the fish oil treated leaves. There were 50 newly hatched nymphs on the untreated leaves and 6, 16, 12, and 18, respectively, on the fish oil treated leaves, from the strongest to the weakest dilution. This would indicate that the fish oil was not so effective on the egg stage as the other materials used in this test. However, the fish oil treated leaves still had a good film of oil left on them and it is possible that the newly hatched nymphs would not survive.

It was noted that the nymphs treated with the *Stantex R* material dried up and turned brown in color within two or three days after treatment and it was very easy to distinguish between the dead and living nymphs. Nymphs treated with the other materials remained plump much longer and did not change color for some time, and it was more difficult to distinguish between the living and dead nymphs.

CONCLUSION.—In summarizing these tests it may be concluded that the citrus whitefly was satisfactorily controlled on gardenias by thorough spraying with 1 and 2 per cent solutions of *Stantex R* emulsified with soap, a 4 per cent solution of *Elgeté*, and $6\frac{2}{3}$, 4 and 2 per cent fish oil emulsions, while *Ortho Brand Garden Volk* and weaker solutions of *Stantex R*, *Elgeté* and fish oil did not give satisfactory control. Also, fish oil was a disagreeable material to handle, and it gave some foliage injury under certain conditions.—11-17-38.

Some Conservation and Ecological Aspects of Mosquito Control

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In order that the anti-mosquito work in Maryland might be in conformance with the principles of conservation of wildlife, it was found necessary to make an ecological study of the tidal marshes in regard to the plants, birds and small mammals, in addition to an intensive study of larval mosquito life, supplemented by records of adult infestation as revealed by mechanical traps.

Collections of larval mosquitoes were made in fresh water and in salt or brackish water. Two tables were compiled, but only that relating to mosquito breeding on tidal marshes is discussed as the major interest is in the effect of ditching on mosquito abundance, on water levels, salinity and the possible succession of plants suitable for muskrat food.

PLANT ASSOCIATIONS AND MOSQUITO BREEDING.—*Spartina alterniflora*, *Spartina patens* and *Scirpus olneyi* are the dominant grasses and sedges on most marshes, with the first named usually occurring in solid stands nearest the main body of salt water, *Spartina patens* on the higher levels away from the water, and *Scirpus olneyi* near the border high land where fresh water enters the marsh. *Tiphia*, principally *augustiflora*, is frequent on some marshes. Typical breeding situations in the dominant plant associations were selected for larval collections.

Potholes in *Spartina patens* and muskrat runs in *Scirpus olneyi* provide the most favorable breeding places for the greatest number of different species of mosquitoes; potholes in *Spartina alterniflora* are next. *Aedes sollicitans* (Walk.) was reared from 15 collections made on *Spartina patens* marsh and from 18 collections made on *Spartina alterniflora* marsh. Five of the 15 collections from *Spartina patens* were from places where the larvae were more than 20 per square foot of water surface, while in 9 of the collections from *Spartina alterniflora* more than 20 per square foot were found. In the muskrat runs of *Scirpus olneyi*, 5 of the 9 collections were from places where the larvae exceeded 20 per square foot of water surface.

Aedes taeniorhynchus (Wied.) was reared from very few collections in 1937. Mosquitoes of this species were found breeding in only four different situations, and then in very limited numbers. In only two cases were they present in numbers over 20 per square foot of water surface, and these were found in *Spartina patens*.

Aedes cantator (Coq.) emerged from collections made in *Spartina patens*, *Spartina alterniflora*, *Scirpus olneyi* and from *Scir-*

pus americanus. Larvae were found in numbers greater than 20 per square foot of water surface from 2 of the 7 collections from *Spartina patens;* from 2 of the 5 collections from *Spartina alterniflora* and from 2 of the 6 collections from *Scirpus olneyi*.

From 6 collections of *Culex salinarius* Coq. made in potholes in *Spartina patens*, 5 situations contained larvae in numbers greater than 20 per square foot of water surface. *Aedes cantator* was reared from 10 collections made in muskrat runs in *Scirpus olneyi*, though larvae were present in numbers greater than 20 per square foot of water surface in only 3 of the 10 collections.

A careful search and study has been made of mosquito breeding in *Scirpus olneyi*, which is one of the principal muskrat foods in Worcester County. During the season of 1936, 19 collections of mosquito larvae were made in *Scirpus olneyi* areas. On only one occasion were larvae found in numbers greater than 20 per square foot of water surface, and only 15 per cent of all collections of larvae from salt or brackish water were made in these areas. However, during 1937, 41 collections were made in *Scirpus olneyi*, and from 15 of these situations larvae were found in numbers greater than 20 per square foot of water surface. In 4 situations larvae were found in numbers from 10 to 20 per square foot of water surface. In the remainder of cases, the abundance of larvae was less than 10 per square foot of water surface. *Aedes sollicitans* was reared from 5 of the 15 situations; *Aedes taeniorhyncus* from 1; *Culex salinarius* from 6; *Anopheles crucians* Wied. from 2; and *Aedes cantator* from 2. In 4 situations, larvae were found in numbers from 10 to 20 per square foot of water surface. In the case of the remaining 16, the abundance of larvae was less than 10 per square foot of water surface.

It would appear from this information that *Scirpus olneyi* marsh is perhaps just as important as a breeding area for *Aedes sollicitans*, *Aedes cantator*, and *Culex salinarius*, as are *Spartina patens* and *Spartina alterniflora* marshes.

EFFECT OF DITCHING ON WATER-LEVELS.—It is apparent from the records that *Scripus olneyi* marshes must be ditched if mosquito breeding is to be controlled, but the stands of this valuable muskrat food must be preserved. Studies of the effect of ditching on water levels show the greatest lowering of water levels on stands of *Scirpus olneyi*, possibly due to the greater porosity of the sod. Calibrated stakes set in holes dug in ditched and unditched marshes were used to determine water levels based on mean low tide at Ocean City, Md. Table 1 represents averages of 44 readings semiweekly from May 14 to October 12:

Table 1.—Showing results of experiments on water table of marsh.

	Spartina patens	*Spartina alterniflora*	*Scirpus olneyi*
Unditched	3.04	2.96	3.08
Ditched	3.03	2.94	2.75
Amount lowering of water table	0.01	0.02	0.33

SALINITY IN RELATION TO MUSKRAT FOOD.—Salinity as well as water level seems to be a factor in the growth of three-square, *Scirpus olneyi*. Twelve salinity stations were established consisting of cans 12 inches in diameter and 30 inches long. Each can was provided with a removable top to prevent rain water from entering and evaporation from taking place. A series of perforations was made in each can, beginning 20 inches from the top and continuing down to within 2 inches of the bottom. The cans were then placed 15 inches in the marsh, and water, to enter a can, had to do so below the level of the marsh. A core 3 inches wide and 22 inches deep was taken out of the center of the soil or marsh inside of the can. Water to fill the hole, left by the removal of the core, had to seep through the marsh.

It is obvious that ditching allows an inflowing of saline water that raises the average salt content to such an extent that it may cause a change in the flora, but by use of dikes and tide gates on marshes where there are large stands of three-square sedge the salinity is reduced, making the most favorable conditions for continued reproduction of this valuable muskrat food. Storms that force salt water up on the marshes scald out large large areas of three-square because such storm water usually recedes slowly but, where ditches are present, the run-off is

much quicker and to that extent ditching improves the conditions for plant growth.

By the addition of 10,500 feet of dikes and 21 tide gates, large areas of muskrat forage have been protected from storm water and by the impounding of fresh water the increased salinity due to ditching has been largely offset. During mosquito breeding, the water level behind the dikes is lowered at regular intervals so as to reduce the amount of breeding in the impounded water.

Records taken for two years indicate a general reduction in the catch of muskrats on ditched marshes, though some areas show an increase. However, records over a long period are necessary for an evaluation of the effect of ditching and dyke construction on muskrat population, but the growth of muskrat food has been preserved and annual fluctuations probably mean little.

SALINITY AND MOSQUITO BREEDING.—Salinity also appears to have a bearing on the breeding of various species of mosquitoes as shown by the following data on the salinity of the water in which the mosquitoes were collected: *Aedes sollicitans*, 61 samples, 37.23 per cent of seawater; *Aedes taenorhynchus*, 5 samples, 30.69 per cent; *Anopheles crucians*, 7 samples, 28.14 per cent; *Aedes cantator*, 23 samples, 24.49 per cent; *Culex salinarius*, 15 samples, 18.93 per cent; *Aedes canadensis* (Theob.) 2 samples, 5.51 per cent; *Culex apicalis* Adams 2 samples, 4.75 per cent.

Aedes sollicitans, *taeniorhynchus* and *cantator* live in water that ranges from practically fresh to sea water, although the optimum salinity is somewhere near the averages.

The important point is that before or during mosquito ditching, all marsh areas have been mapped to show the various solid stands of plants so that future workers may plot any changes that may occur, thereby determining without guess work or recourse to memory the effect of ditching on the ecological succession in any mapped area.

DITCHING IN RELATION TO DUCK FOOD.—Ducks feed to a considerable extent upon widgeon grass, *Ruppia maritima*, which grows abundantly in the ponds in the marshes. However, many of these ponds dry up during the summer and the growth of widgeon grass is lost thereby as duck food. By the digging of a ditch 6 inches deep from the main 20-inch ditch into these ponds, water is maintained in the ponds during the summer, fish are allowed access and the growth of widgeon grass is preserved. Deep ditches dug into these ponds would undoubtedly destroy them as resting and feeding places for ducks, and if no ditches were dug into the ponds many of them would dry up during the summer. Therefore, the anti-mosquito work may be considered beneficial for the preservation of plant life on duck feeding and resting areas. In addition, at some places it was found advisable to deepen some ponds by cutting T-shaped ditches through the center that tended to maintain a supply of water through the summer. In some instances actual construction of ponds was undertaken by utilizing the sods taken out of the anti-mosquito ditches for the construction of the banks of the ponds, especially in those areas that are owned by gun clubs on which permission to do anti-mosquito work could not otherwise be secured.

The timing of ditching with relation to nesting habits of the common duck species that inhabit our marshes is equally important. Most ditching is done on areas known to be nesting sites for black ducks before or after April and May. Likewise, no burning of marshes to facilitate anti-mosquito work has been done. As a consequence there has been an increase of nesting of black ducks on the marshes that have been so handled. Reports that young ducks are drowned in the ditches seems to be rather a far-fetched idea, if the reports of caretakers of gun clubs can be credited. They report that the young ducks use the mosquito ditches near their nests, and no reports have been received of drowned ducks being found in the ditches.

An attempt has been made to do those operations necessary for mosquito control in such a manner as to interfere the least with the balance of wildlife as it existed at the beginning of the work, to improve conditions for wildlife feeding, breeding and resting and to collect data upon which definite conclusions, instead of conjectures based on prejudices, can be formulated.—11-17-38.

Comparative Results Obtained by the Use of Several Mosquito Traps in a Limited Area

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There is little published data regarding the number of mosquito traps needed in a locality to provide an adequate cross section of the mosquito population. Van Derwerker (1935) has made some observations of this nature and stated that "one trap to every five square miles in a controlled territory should be sufficient for a clear picture of mosquito conditions."

TRAP SITE.—Newark, the site of the University of Delaware, was chosen for concentrated trapping studies. The town is located in the extreme northwestern portion of the state. Included within its boundaries are about 1,000 acres of land and a population of approximately 4,500 people. No antimosquito measures had previously been taken in this community.

The town is sufficiently distant from the Delaware Bay shore so that comparatively few salt marsh mosquitoes are present. Numerous drain ditches on the outskirts of town, a small polluted run, temporary and semipermanent pools of standing water and various water-holding receptacles within the town limits probably account for most of the mosquito annoyance.

Three traps (the New Jersey vertical model) were located in an older and more densely populated section, while two others, one of which was outside the town limits, were in comparatively new and less congested areas, fig. 1.

The traps were operated continuously for a period of 27 days in the month of July, 1937. An effort was made to locate each trap so that as nearly as possible each received about equal protection from wind by the adjacent shrubbery.

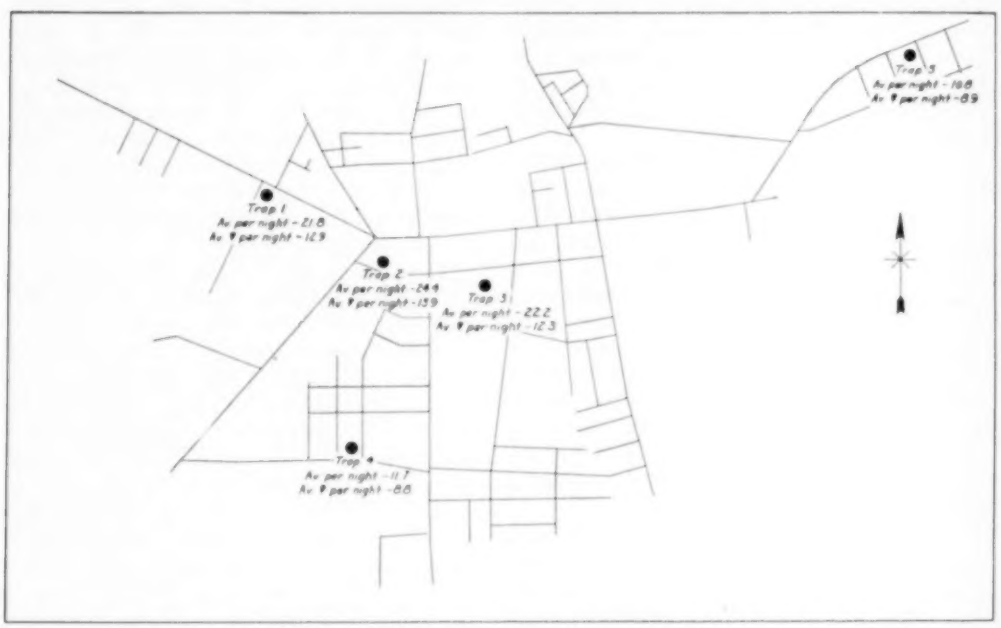
Trap 1
Av per night - 21.8
Av ♀ per night - 12.9
Trap 2
Av per night - 24.9
Av ♀ per night - 15.9
Trap 3
Av per night - 22.2
Av ♀ per night - 12.3
Trap 4
Av per night - 11.7
Av ♀ per night - 8.8
Trap 5
Av per night - 19.8
Av ♀ per night - 8.9

FIG. 1.—Map of Newark, Del., showing trap locations and including averages for total mosquitoes and female mosquitoes collected per night.

COLLECTION DATA.—Table 1 presents the collection data for each trap for the entire period. It is apparent that the mosquito problem in Newark is not acute, inasmuch as the average per night is considerably below the catch of 24 female mosquitoes which New Jersey authorities consider is the maximum of tolerance beyond which serious annoyance is ex-

perienced. Usually, tabulations of this nature do not include males or, if they do, the sexes are not separated. It was thought that a presentation of the comparative numbers of the two sexes might be of interest. The females collected in the first three of the five traps comprised approximately 59 per cent, 57 per cent and 56 per cent of the respective total collections. In the two remaining traps the proportion of females was higher; namely, 76 per cent and 83 per cent. Of all the collections 63 per cent were females.

Table 1.—Detailed collection records for five mosquito traps operated in Newark, Del., during July, 1937.

Trap	Mosquitoes						
			Males		Females		
	Number Collected	Average Per Night	Number	Per Cent	Number	Per Cent	Average Per Night
1	590	21.8	241	40.8	349	59.2	12.9
2	660	24.4	285	43.2	375	56.8	13.9
3	599	22.2	266	44.4	333	55.6	12.3
4	315	11.7	76	24.1	239	75.9	8.8
5	291	10.8	50	17.2	241	82.8	8.9
Total	2,455	90.9	918	37.4	1,537	62.6	56.9

Traps 1, 2 and 3 averaged 12.9, 13.9 and 12.3 female mosquitoes, respectively, per night which means that they collected essentially the same number of mosquitoes. Traps 4 and 5 collected 8.8 and 8.9 mosquitoes, respectively. Thus the five traps are divided into two groups, with the first collecting approximately four more mosquitoes per night than the second. The trap locations were examined with the thought of ascertaining any environmental differences that might exist. It was certainly not a matter of elevation, since the difference between that of the highest trap and the lowest was but 43 feet. Other visible conditions appeared to be nearly equal. Population density appears to be the only explanation. The traps capturing the largest numbers of female mosquitoes were located in old and established sections of Newark. The other traps, although on opposite sides of the town, were placed in comparatively new real estate developments with a much lower population density. Headlee (1936) has indicated that both *Aedes vexans* (Meig.) and *Culex pipiens* L. tend to migrate in the direction of great population regardless of wind direction. It is logical to believe that this phenomenon exists though possibly in a lesser degree in the case of a comparatively small community such as the one under consideration. In addition, the more congested areas of the town probably offer better opportunities for breeding, especially as regards the house mosquito, *C. pipiens*. Water-retaining receptacles, such as empty cans and rain barrels, are naturally found in greater abundance in thickly populated districts. A greater concentration of houses in an area also increases the possibilities of breeding in rain gutters.

A sufficiently accurate record of mosquito conditions is presented by the collection data for any one of the five traps, regardless of its position in either group, to make possible an intelligent attack upon the problem if it were warranted. Thus, it is evident, for a town of this size and with *Culex pipiens* and *Aedes vexans* the principal species involved, that one trap is all that is necessary. It seems indicated that the trap should be located near the center of population. Proximity to salt marshes, considerable differences in elevation between various sections of the same town and, more important possibly, unsanitary conditions over a considerable area, might require the operation of more than one trap to obtain a correct estimate of mosquito prevalence.

A total of 18 species of mosquitoes were collected by the traps, table 2.

Twelve per cent (284) of the total mosquitoes identified were females of *Culex salinarius*. In view of the fact, however, that the males were not separated from

those of *C. pipiens* it appeared advisable to combine the two species in the table. Thus 65.05 per cent of the total collections was composed of these two species and, of these two, 60.5 per cent were females. The other species of consequence, *Aedes vexans*, constituted 25.4 per cent of the total. Sixty per cent of this species proved to be females. None of the common salt marsh species, *Aedes sollicitans*, *A. cantator* and *A. taeniorhynchus*, amounted to as much as 1 per cent of the total. But one male of *A. cantator* was collected. The genus *Anopheles* was also numerically insignificant with only *An. punctipennis* exceeding 1 per cent. Males of both this species and *An. crucians* were taken. The single specimen of *An. walkeri* is worthy of note since the species had not been collected previously in this locality. The remaining species listed are interesting merely as a matter of record. A total of 2,455 mosquitoes was captured, of which 1,537 or 63 per cent were females. Nevertheless, it seems evident from the figures presented that males are more active than is generally supposed. MacCreary & Stearns (1937) in a study of mosquito migration across Delaware Bay have previously indicated that such is the case.

SUMMARY.—Five mosquito traps were operated in various locations in a comparatively small community (Newark, Del.) for 27 consecutive days during July, 1937. Three of the traps that were located in an older and more densely populated section of the town averaged nearly identical collections of female mosquitoes; the records for the other two traps, in less congested areas, are likewise in agreement but show slightly fewer mosquitoes per night. The attraction set up by the densely populated district and the more opportunities therein for the breeding of *Culex pipiens* were probably the factors influencing the distribution of the mosquitoes as measured by the trap collections. It would seem, therefore, that, if unusual topographical or sanitary conditions do not exist, one trap properly located should be sufficient to provide an accurate estimate of mosquito density in a community of this size (4,500 people).

Nearly 63 per cent of all the mosquitoes collected were females. Approximately 60

Table 2.—Collection records showing species and sex of the mosquitoes collected in five traps at Newark, Del., during July, 1937.

Genus	Species	Number	Per Cent	Males		Females	
				Number	Per Cent	Number	Per Cent
Anopheles	*punctipennis* (Say)	25	1.01	6	24.0	19	76.0
	quadrimaculatus Say	3	*	0	—	3	100.0
	walkeri Theob.	1	*	0	—	1	100.0
	crucians Wied.	22	0.90	1	4.5	21	95.5
Aedes	*vexans* (Meig.)	624	25.40	252	40.4	372	59.6
	sollicitans (Walk.)	13	0.50	0	—	13	100.0
	cantator (Coq.)	23	0.90	1	4.3	22	95.7
	taeniorhynchus (Wied.)	2	*	0	—	2	100.0
	triseriatus (Say)	6	*	1	16.7	5	83.3
Culex	*apicalis* Adams	59	2.40	14	23.7	45	76.3
	pipiens L. / *salinarius* Coq.	1,597	65.05	630	39.5	967	60.5
	restruans Theo.	40	1.60	12	29.9	28	70.1
Psorophora	*ciliata* (F.)	8	*	0	—	8	100.0
	columbiae (D. & K.)	26	1.05	1	3.8	25	96.2
	ferox (Humb.)	2	*	0	—	2	100.0
Uranotaenia	*sapphirina* (O.S.)	3	*	0	—	3	100.0
Orthopodomyia	*signifer* (Coq.)	1	*	0	—	1	100.0
Totals	18	2,455	100.00	918	37.4	1,537	62.6

* Less than 0.5 per cent.

per cent of *Aedes vexans*, which constituted nearly one-fourth of the total catch, were of that sex. *Culex pipiens* and *C. salinarius* together comprised 65 per cent of all material and of this number 60 per cent were females. Nevertheless, from the data presented, it is evident that there is more flight activity among male mosquitoes than is generally believed.—11-17-38.

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How Petroleum Oil Kills Certain Mosquito Eggs*

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THOMAS J. HEADLEE, *New Jersey Agricultural Experiment Station, New Brunswick*

For years there has existed doubt as to the specific action of petroleum oil on insect eggs. In practical experience it has been repeatedly shown that petroleum oils kill some insect eggs and that different kinds of petroleum oil are less or more effective in killing insect eggs.

In an effort to throw some light on these matters the writers selected a series of 28 petroleum oils covering a wide range of physical properties and tested them in undiluted form on the eggs of a well known mosquito, *Aedes aegypti* (L.). The results are set down in table 1 and fig. 1.

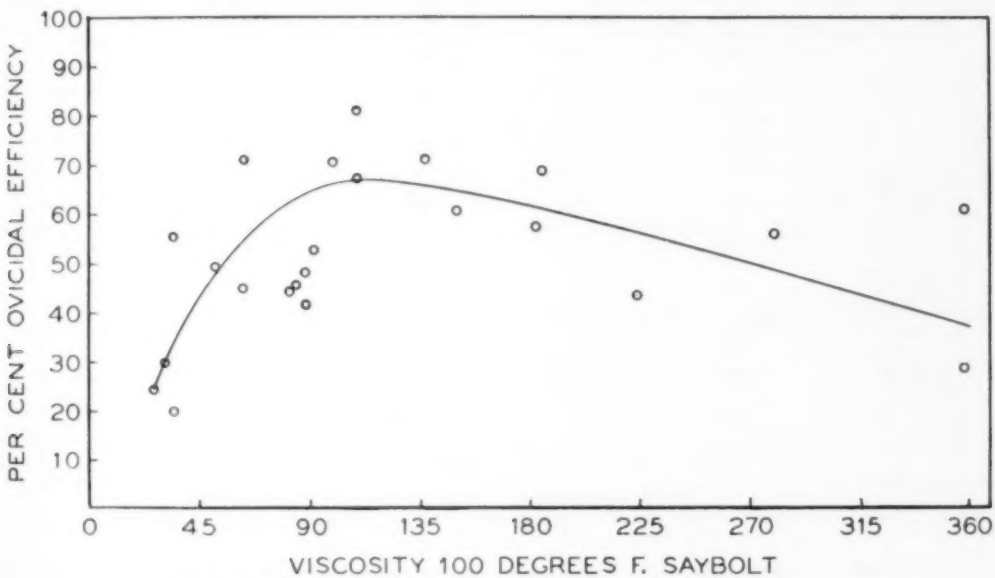

FIG. 1.—Relation of viscosity of petroleum oils to ovicidal efficiency.

It thus appears that degree or percentage of kill has a rough relation to viscosity. The low percentage of kill which appears in the low viscosity oils rises to a certain maximum of about 108 viscosity and then falls off as the viscosity in-

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

creases. It is obvious that this relationship is not sharp but constitutes a clearly discernible trend. Of the oils tested *Zerice 40*, an oil manufactured by the Standard Oil Company of New Jersey, gave the highest kill of mosquito eggs. This oil is a light spindle oil having a viscosity of 108 seconds Saybolt at 100 degrees F. and a

POSSIBLE METHODS OF DESTROYING EGGS.—After the writers had thought over the ways in which petroleum oils might kill these mosquito eggs it seemed to them that destruction might result through penetration of the chorion, through chemical action on the chorion or by suffocation of the developing em-

Table 1.—Effect of various petroleum oil fractions on the eggs of a mosquito, *Aedes aegypti* (L.).

NAME	VISCOSITY 100°F. SAYBOLT	FLASH POINT		PER CENT VOLATILITY IN RELATION TO KEROSENE AND DEOBASE	PER CENT OVICIDAL EFFICIENCY
		Pensky Marten	Cleveland		
Deobase	30	—	—	100	24
Kerosene	32	—	125	100	30
Bayol D	33	170	—	82	19
Bayol D-1	33	188	—	77	54
Bayol F	52	310	—	5	48
Forum 35	64	—	320	0	44
Nuto 35	64	—	325	20	72
Marcol	84	—	—	31	43
Marcol J	86	325	—	0	44
Bayol J-16	88	365	—	0	40
Bayol J	88	370	—	0	45
85 R	93	330	—	0	52
Spinesso 38	99	—	365	21	69
Forum 40	109	—	360	0	66
Zerice 40	109	—	340	0	79
Tilura 42	138	—	400	12	69
Teresso 43	149	—	415	9	58
Forum 45	188	—	390	0	54
Standard Oil S.A.E. 10	193	—	425	0	67
Nujol	222	380	—	0	43
Faxon 50	294	—	415	0	54
Primol D	352	385	—	0	58
Standard Oil S.A.E. 20	352	—	440	0	29
Standard Oil S.A.E. 30	550	—	470	0	25
Standard Oil S.A.E. 40	707	—	495	0	40
Standard Oil S.A.E. 50	1195	—	520	0	34
Standard Oil S.A.E. 60	1551	—	525	0	40
Standard Oil S.A.E. 70	1955	—	535	0	24

$$\text{Ovicidal efficiency} = \frac{\text{Per cent hatch in check} - \text{Per cent hatch in treatment}}{\text{Per cent hatch in check}}$$

By ovicidal efficiency is meant the relationship of the per cent hatch of the oil treated eggs to the per cent hatch of the check.

Flash point of 340 by the Cleveland Open Cup method; it is extremely nonvolatile.

It is now necessary to describe the nature of the *Aedes aegypti* egg. The outer cover of this egg is, of course, the chorion and it is covered with pits or indentures. These pits are pits only and not perforations, fig. 2.

bryo. Oil penetration of the chorion might conceivably occur either as a gas or as a liquid. If it occurs as a gas it would be anticipated that the more volatile petroleum oil fractions would be more effective. Such, however, does not prove to be the case as shown in table 1.

Inasmuch as no tests were made by enclosing the eggs in a chamber saturated

with volatilized oil, it cannot be said that the vapors of certain petroleum oils might not, when employed under enclosed conditions, result in the death of the mosquito eggs. From a practical standpoint, however, it seems clear that application of these volatile oils in the open does not result in a high destruction. If the oil penetrates as a liquid, traces of it should be found within the egg. Such traces were diligently sought in microscopic examination, not only on eggs treated with oils alone but on eggs treated with oils carrying a range of dyes, such as *Sudan II*, *Sudan III* and *Oil Red I*. In no case was any evidence of penetration whatever found. The conclusion was, therefore, reached that killing of the mosquito eggs was not due to their penetration by oil.

Evidences of chemical action on the chorion were also diligently sought but the chorion of untreated eggs seemed identical in hardness, brittleness, and ocular appearance with the untreated eggs. Consequently the conclusion was reached that there was no appreciable chemical reaction between the oils and the chorion.

This left the possibility of suffocation. Suffocation might conceivably mean merely oxygen starvation or it might mean a direct poisonous effect of high concentrations of carbon dioxide or both. To find out the effect of oxygen starvation, the writers subjected untreated eggs to an atmosphere of oxygen, an atmosphere of nitrogen and an atmosphere of hydrogen. The results are set forth in table 2.

Thus it appears that subjection of the eggs for 24 hours to nitrogen kills from 81 to 96 per cent of the eggs; to hydrogen, from 80 to 98 per cent. Subjection to an atmosphere of oxygen, of course, insures an abundant supply of that important gas and results in no destruction of the eggs. Exposure to nitrogen and hydrogen deprives the egg of its oxygen and results in high destruction in 24 hours and complete destruction in three or more days. These effects seem to indicate that de-

FIG. 2.—Eggs of *Aedes aegypti* (L.).

Table 2.—Mosquito eggs treated with oxygen, nitrogen and hydrogen.

TREATMENT	NUMBER OF EGGS	NUMBER HATCHED	PER CENT HATCH	OVICIDAL EFFICIENCY
Check	162	136	84	0
Oxygen—24 hours	148	126	85	0
Check	122	117	96	0
Nitrogen—24 hours	212	40	18	81
Nitrogen— 6 days	105	0	0	100
Check	260	250	96	0
Nitrogen—24 hours	230	9	4	96
Nitrogen— 6 days	205	0	0	100
Check	115	114	99	0
Nitrogen—3 days	270	0	0	100
Check	58	39	69	0
Hydrogen—24 hours	77	1	1	98
Hydrogen—24 hours	51	5	10	80

privation of oxygen is highly destructive to the eggs of this mosquito.

We have next to examine the effect of an atmosphere of carbon dioxide. The facts are set forth in table 3.

Table 3.—Mosquito eggs treated with carbon dioxide.

Treatment	Number of Eggs	Number Hatched	Per Cent Hatch	Ovicidal Efficiency
Check	158	139	87	0
Carbon dioxide—24 hours	145	62	42	51

These facts show that while an atmosphere of carbon dioxide produces a destruction of 51 per cent it is not comparable to the destruction wrought by such an inert gas as nitrogen and we cannot, therefore, attribute any direct poisonous effect due to concentration of carbon dioxide but must rather attribute such kill as does occur to oxygen starvation.

subjected to atmospheres of oxygen and carbon dioxide. The results are set forth in table 4.

The eggs treated with *Zerice 40*, as were those of the check, were exposed to the natural atmosphere. Inasmuch as *Zerice 40* treated eggs exposed to the natural atmosphere gave practically the same kill as the *Zerice 40* treated eggs exposed to atmospheres of oxygen and carbon dioxide, it seems clear that *Zerice 40* as well as other oils kill eggs of this mosquito by establishing a coating on the chorion which is impervious to oxygen.

Table 4.—Mosquito eggs treated with oil and with oil and oxygen and carbon dioxide.

Treatment	Number of Eggs	Number Hatched	Per Cent Hatch	Ovicidal Efficiency
Check	162	136	84	0
Zerice 40—24 hours	224	12	5.3	93.7
Oxygen—24 hours	148	126	85	0
Zerice 40 and oxygen—24 hours	198	9	4.6	94.6
Check	158	139	87	0
Zerice 40—24 hours	174	11	6.3	92.8
Carbon dioxide—24 hours	145	62	42	51
Zerice 40 and carbon dioxide—24 hours	200	12	6	93.1

Thus far it appears from these studies and examinations that the apparent suffocation of the eggs of *Aedes aegypti* is due to deprivation of oxygen.

Since the oils employed in treatment of these mosquito eggs do not seem to penetrate the chorion and since no evidence of chemical reaction between the chorion and the oils could be found, their effectiveness in destroying the eggs must be due to depriving the oil treated eggs of the necessary oxygen supply. To test out this idea eggs were treated with the most toxic oil, which was *Zerice 40*, and then

CONCLUSION.—It may be concluded from this work:

(1) Eggs of *Aedes aegypti* are killed when coated with petroleum oil by oxygen starvation.

(2) The more nearly perfect the oil coating, the more quickly the kill is accomplished.

(3) The variation in killing power of different petroleum oils is probably a factor of either too short a period of oil retention or a failure of the oil to make a closely applied and complete seal.—11-17-38.

THE Colorado quarantine relating to the peach mosaic disease was reissued on February 8, 1939, to add to the regulated areas, in the seven known infected states, counties which had been found infected in 1938.

THE so-called "Red Stele" disease of strawberry plants is the subject of regulations placed by New Jersey on February 14, 1939, on all shipments of such plants coming into the state, or shipped within the state.

Importance of Controlled Mating of Queens in the Development of High Producing Strains of Honeybees*

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The development of a high producing strain of honeybees for New Jersey conditions has been one of the major problems of the apicultural division of the New Jersey Agricultural Experiment Station since the establishment of this division in 1924. The information summarized in this paper gives results obtained during the past five years which indicate that drone selection in mating plays an important role in the honey producing ability of the queen bees.

HISTORICAL.—In 1924 an out apiary of 60 colonies of bees was established in the summer honey flow area in northern New Jersey, which has been used primarily for production studies. The original colonies in this apiary were headed by Italian queens obtained from the leading queen breeders in the United States and Europe. From this original stock, selection of the better producing colonies as breeders has been made from year to year. As it was desirable to control the mating of the queens in this study, a mating station was established on the plains near Chatsworth, N. J. The plains area was selected because it is an extensive area covered with a scrub growth of pine and oak which is free from wild bees and isolated from other beekeeping areas. Each year nuclei containing virgin queens were taken to the mating station and allowed to mate with selected drones. These mated queens were then placed in the production yard where the honey producing ability of their colony was compared with other races and strains of bees. After a number of years of testing and selecting, the best producing strain appeared to be an inbred strain of Italian bees which had been developed at the New Jersey Agricultural Experiment Station because of their resistance to European foulbrood. While this strain of bees exhibited high honey producing ability and great resistance to European foulbrood, it was not ideal or uniform in many other respects. As it was desirable to improve this strain of bees by further selection the entire production yard was requeened with this stock in 1931, and thereafter the mating of queens was carried on at the production yard as well as at the mating station on the plains. The queens obtained were designated as yard mated or controlled mated queens, and careful records of each group were obtained yearly. Although every effort was made to prevent yard mated queens from mating with drones from undesirable colonies the records seemed to indicate that the honey production of colonies headed by controlled mated queens was superior to the yard mated queens. In order to test these results further the following experiment was set up in 1933.

EXPERIMENTAL PROCEDURE.—Daughters of one or more breeding queens were reared under similar conditions and mated at the production yard or at the mating station. The queens mated at the production yard were designated as yard mated queens while those mated at the mating station were designated as controlled mated queens. These queens were introduced into established colonies in late August or early September, and the honey production ability of their colony obtained the following year. The general procedure followed is discussed under their separate headings.

BREEDING QUEENS.—All selections of breeding queens have been made primarily from the standpoint of honey production, with secondary consideration being given to such characteristics as color, gentleness, type of brood nest and general behavior. Tentative selection of breeding queens is made at the close of the summer honey flow in July, and at that time a limited number of queens are raised from each breeder for preliminary testing. Final selection of a queen as a breeder is made the second year, after the colonies headed by their daughters have been under observation for a full year. After final selection as a breeder, such queens are placed in small colonies of bees to lengthen their time of service. Usually but one new breeder is selected each year, although it is not uncommon to have five or six tested breeders available at one time.

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.

BREEDING DRONES.—The selection of desirable drones is also based on honey production records, and drones from desirable colonies are tested before their final selection. The usual procedure is to supply a selected colony with an abundant amount of drone comb, and when filled with drone brood these combs are transferred to a drone free colony and taken to the mating station. These drones are then allowed to mate with daughters of one of the older breeders, whose daughters have been mated to an established drone breeder and are heading colonies in the production yard. Final selection of a drone breeder is based on the performance of the queens they have mated with when compared with similar queens mated to an established drone breeder. Because of the restricted number of colonies of bees available for this work, the number of selected drone breeders is kept at a minimum and it is unusual to have more than two tested drone breeders available at any one time.

Table 1.—Average honey production of colonies headed by controlled mated queens and yard mated queens for the period 1934 through 1938.

YEAR	NUMBER COLONIES		AVERAGE HONEY PRODUCTION	PER CENT INCREASE IN PRODUCTION OF CONTROLLED MATED QUEENS
1934	26	Yard mated queens	144	
	12	Controlled mated queens	190	32
1935	10	Yard mated queens	52	
	12	Controlled mated queens	66	27
1936	6	Yard mated queens	68	
	8	Controlled mated queens	79	15
1937	18	Yard mated queens	95	
	16	Controlled mated queens	116	22
1938	24	Yard mated queens	97	
	15	Controlled mated queens	125	29

MATING STATION PROCEDURE.—The mating station on the plains is located in an area that is very undesirable as a bee location. Nectar plants in the immediate area are restricted to small scattered areas containing blueberry, laurel and clethra. Water is usually available from the small streams bordering this area.

The usual procedure used at the mating station is as follows. At the start of the breeding season a single drone colony is established at the mating station, by making up a droneless and queenless colony of bees containing combs of drone brood from an established drone breeder. This colony is supplied with additional drone and worker brood from time to time and is also used as a nucleus to mate queens throughout the season. As soon as drones are available in sufficient numbers the virgin queens are transported to the mating station in 2- and 3-frame nuclei and remain at this location until they are mated, when they are returned with the nuclei to the production yard. Particular care is necessary to keep these nuclei free from drones when they are taken to the mating yards. Whenever it is desirable to change the drone breeders, the entire yard must be removed and the new drone colony established in its place.

PRODUCTION YARD PROCEDURE.—Mated queens are introduced into established colonies as soon as their performance in the nuclei demonstrate they are properly mated. One pair of wings of each queen is clipped before introduction in order to aid in the later identification of these queens.

Management in the production yard consists chiefly of providing plenty of super room. Queens are allowed two standard 10-frame hive bodies for a brood nest up until the start of the honey flow, when they are restricted to one super. All colonies are standardized in brood, bees and stores before they are prepared for

winter. All colonies have been wintered in two hive bodies without any protection other than a suitable windbreak except in the winter of 1937–38 when one-half of the colonies were packed. The 1938 results are included in this study because the difference in average honey production between packed and unpacked colonies was only two pounds.

Production records are obtained by a series of weighings in which the entire hive is weighed. Such weighings are made at the time colonies are prepared for winter, early in the spring and at monthly intervals throughout the summer honey flow period. Honey production is computed by subtracting the initial spring weighing from the weighing at the close of the honey flow after all tare weights have been deducted.

RESULTS AND DISCUSSION.—The results of this series of experiments have been summarized in table 1.

The results obtained indicate a decided and consistent increase in honey production in favor of the controlled mated queens and indicate the need for drone selection in the further development of our present strains of bees. While the table presents only the averages it is interesting to note that the individual production records of the controlled mated queens is fairly consistent in any one year, while the records of the yard mated queens have a much greater range. At the start of this work it was thought that the production of the yard mated queens would gradually approach the production of the controlled mated queens as the stock in the production yard would be continuously improved by the requeening of the poorer producing colonies. At the present time, there is no indication of a trend in this direction, which seems to indicate that continuous selection is desirable.—11-17-38.

Further Notes on the Control of the Harlequin Bug

HARRY G. WALKER and LAUREN D. ANDERSON, *Virginia Truck Experiment Station, Norfolk*

Since the serious outbreak of the harlequin bug, *Murgantia histrionica* (Hahn), in 1932 (Walker & Anderson 1933),* the growers of large acreages of truck crops have kept this pest under control by the cultural practices recommended by White & Brannon (1933). However, this insect continues to be a rather serious pest of cruciferous crops in small truck gardens and home gardens nearly every year because either the owners or their neighbors do not follow the proper clean-up measures. As the spray of concentrated derris extract (5 grams rotenone per 100 cubic centimeters) plus soap is usually not readily available and weather conditions are such that the concentrated soap spray (Fulton 1930) and derris dust (Walker & Anderson 1934) do not give very satisfactory results, an effort has been made to find a more readily available and effective insecticide for the control of this pest.

* Because of a misunderstanding, footnote 4 on the bottom of page 133 JOUR. ECON. ENT., 1933, was incorrectly stated. It should have read as follows: "The authors deeply appreciate the collaboration and help of Mr. L. W. Brannon, Bureau of Entomology, U. S. Department of Agriculture, during the early part of the control experiments, and are especially indebted to him for the suggestion of the use of *Serrid*, a concentrated derris extract containing 5 grams rotenone per 100 cubic centimeters, for the control of the harlequin bug."

Tests conducted in 1934 with *Loro*, an aliphatic thiocyanate, indicated that dilutions of 1/200 of this material had very little effect on the harlequin bug.

DERRIS POWDER AS A SPRAY.—Preliminary tests conducted in the summer of 1936 with a derris powder containing 4 per cent rotenone and used at the rate of 4 and 6 pounds to 50 gallons of water gave promising results. Later, following our suggestions, Henry McCann, a Smith-Hughes agricultural instructor, at Holland, Va., reported that he had obtained very good results with derris powder used at the rate of 4 pounds to 50 gallons of water.

CAGE TESTS.—In cage tests on adult harlequin bugs conducted on July 29, 1938, a warm, sultry, sunshiny day, a cubé powder containing about 6 per cent rotenone used at the rate of 4 pounds to 50 gallons of water, to which *SS-3* (now called *Grasseli Spreader*, a sodium oleyl sulfate plus a resin sticker) had been added at the rate of 1/600, gave 100 per cent control. A *Pyrocide* dust containing 2 per cent pyrethrins gave 32 per cent control and *Elgeté*, an emulsified peanut

Table 1.—Results of spraying cabbage for the control of harlequin bug nymphs, September 23, 1938.

Sprays Used	Dilution	Number of Nymphs	Per Cent Control
Stantex R *Stantex Spreader Soap*	1/50 1/200	80	85
Cubé *Stantex Dispersing Oil* *Stantex Spreader Soap*	4–50 1/200 1/200	80	84
Stantex R *Stantex Spreader Soap*	1/100 1/200	80	72
Cubé *Pyrolene*	4–50 1/200	80	72
Cubé *Aresket*	4–50 1/200	80	71
Cubé *Red "A" Soap*	4–50 1/200	80	61
Cubé *SS-3*	4–50 1/200	80	55*
Cubé	6–50	80	51
Elgeté	1/25	80	49
Cubé	4–50	80	46
Stantex R *Stantex Spreader Soap*	1/200 1/200	80	34
Cubé	2–50	80	22
Check	—	160	0
Difference required to be significant	—	—	26

* Nymphs were unusually scarce in areas treated with this spray and that probably accounts for its poor showing.

oil, used at the rate of 1/100, gave 16 per cent control.

FIELD TESTS.—Cabbage plants rather heavily infested with harlequin bug nymphs were sprayed on September 23, 1938, with 13 different materials. It was a sunshiny day with a temperature of 77 degrees F., a relative humidity of 48 per cent and a light southwest wind that blew part of the time. The materials used and the results obtained are given in table 1.

Stantex R is a mixture containing 80 per cent *Stantex Dispersing Oil*, which is a mineral oil containing a small percentage of oleic acid and a spreader, and 20 per cent of a derris extract in camphor sassafras base oil containing 5 grams of rotenone per 100 cubic centimeters. *Stantex Spreader Soap* contains 50 per cent of a potash soap and 50 per cent *Pyrolene M. P.*, which is the sodium salt of a synthetic wax. *Aresket* is an alkylated sulfonated diphenyl. *Red "A" Soap* is a liquid soap containing about 60 per cent moisture. The cubé powder used in these experiments had a rotenone content of 6 per cent.

The per cent control was calculated from counts of 20 nymphs from 4 different parts of the rows which had been treated with each material. In making the counts it was noted that the nymphs were very scarce on the row treated with the mixture of cubé and *SS-3*. The plants in these rows were larger and relatively free from injury, consequently affording better protection for the few nymphs that were present. This made control much more difficult and probably accounts at least in part for the poor results obtained with this spray.

A similar spray test was conducted on

Table 2.—Results of spraying cabbage for the control of harlequin bug nymphs, October 5, 1938.

Sprays Used	Dilution	Number of Nymphs	Per Cent Control
Cubé *SS-3*	4–50 1/200	62	79
Stantex R *Stantex Spreader Soap*	1/50 1/200	70	63
Cubé *Pyrolene*	4–50 1/200	63	62
Cubé *Aresket*	4–50 1/200	80	59
Stantex R *Stantex Spreader Soap*	1/100 1/200	71	50
Cubé *Red "A" Soap*	4–50 1/200	65	42
Cubé	6–50	73	29
Stantex R *Stantex Spreader Soap*	1/200 1/200	68	29
Elgeté	1/25	59	27
Cubé	4–50	63	19
Check	—	77	1
Difference required to be significant	—	—	12

October 5, 1938, a sunshiny day with a light breeze blowing, a temperature of 64 degrees F. and a relative humidity of 63 per cent. In this test the nymphs were sprayed where they were feeding on the plants, then collected and placed in screen cages over treated plants as soon as possible after spraying.

While collecting the nymphs, it was observed that from 15 to 25 per cent of the nymphs placed in the cages had been hidden in protected places on the cabbage plants and had not been hit by the spray. The cages were examined on October 7 and 10 and the number of dead and active nymphs recorded, the results of which are given in table 2. If an allowance is made for those insects not hit by the spray, it is apparent that cubé 4–50 in combination with a good wetting agent and also *Stantex R* at 1/50 emulsified with soap gave good control of this pest.

Three cubé dusts and two pyrethrum dusts were included in this test, the results of which are given in table 3. It may be observed that even the cubé dust containing 2 per cent rotenone failed to give satisfactory results under these weather conditions; further, that the pyrethrum dusts used were not so effective as the best cubé dust.

COMPARISON OF CAGE AND FIELD TESTS.—Another experiment was conducted on October 15, 1938, to test the effectiveness of the *Stantex R* and cubé sprays as compared with that of a concentrated derris extract plus soap spray which had given the best results in the experiments reported by Walker & Anderson (1933) and with that of a 2 per cent by weight of *Ivory Soap* spray. The cubé dusts were also included in the test. The experiment was conducted on a cloudy day with a light northeast breeze blowing, with a temperature of 68 degrees F. and with a light mist falling part of the time the materials were being applied. Whereas, only nymphs were used in the two previous tests, in this experiment adults and fully grown nymphs were about equally abundant. Many of the nymphs that were not killed changed into adults before the tests were completed. This experiment was divided into two parts. In one, the bugs were sprayed where they were feeding on the plants, then collected and placed in cages over treated plants. In the other part, they were collected, placed in cages and treated where all bugs were assured of being hit by the spray or dust and then placed over untreated plants. Final counts were made in the sprayed cage tests on October 19, while the final counts were not made in any of the dusted tests or the field tests until October 25. Based on the reaction of the bugs in the field tests, it is believed that over 95 per cent of the bugs in all of the cage tests would have died had the final counts been delayed until October 25. The results of this experiment are given in table 4.

Table 3.—Results of dusting cabbage for the control of harlequin bug nymphs, October 5, 1938.

Dusts Used	Per Cent Active Ingredients	Number of Nymphs	Per Cent Control
Talc Cubé	2.0 rotenone	64	38
Pyrocide	0.2 pyrethrins	60	25
Talc Cubé	0.5 rotenone	62	11
Talc Cubé	1.0 rotenone	60	8
Talc *Stimtox A*	0.3 pyrethrins	60	7
Check	—	77	1
Difference required to be significant		—	12

In general, the cage tests gave higher and quicker kills than the field tests, and the sprays killed faster than the dusts. In fact, many of the nymphs seemed to stop feeding after dust was applied and apparently died from starvation and desiccation rather than from the direct effect of the dust. It is interesting to note that a cubé dust containing 0.75 per cent rotenone, applied on October 15, during a light drizzle of rain, gave 83 per cent control as compared with 38, 8 and 11 per cent control, respectively, from cubé dusts containing 2, 1 and 0.5 per cent rotenone applied on October 5, a sunshiny day with a relative humidity of 63 per cent. This agreed with earlier observation in that derris or cubé dusts applied just before or during a rain will give much

better control of harlequin bugs than those applied during a dry period. It is also interesting to note that the 2 per cent *Ivory Soap* spray gave 100 per cent control in the cage tests as compared with 53 per cent control in the field test.

In addition to these tests were others reported from Drakes Branch, Va., where growers were having considerable trouble with harlequin bugs in the fall of 1938. Very good control of this pest was obtained with sprays of derris or cubé powder having a 5 per cent rotenone content when used at the rate of 4 pounds to 50 gallons of water.

CONCLUSION.—Thoroughly spraying plants infested with harlequin bugs with a mixture containing 4 pounds of derris or cubé powder (rotenone content 5 or 6 per cent) to 50 gallons of water, to which a good wetting agent has been added, will give good control of all harlequin bugs hit by the spray. Further, 1 part of *Stantex R* emulsified in 50 parts of water and thoroughly applied will give good control of this pest, as will the concentrated derris extract plus soap spray previously recommended. On large plants where the bugs are well protected it may be necessary to spray two or three times at weekly intervals to insure good control.—11-17-38.

Table 4.—Results of field and cage tests for the control of the harlequin bug, October 15, 1938.

TREATMENT USED	DILUTION	CAGE TESTS		FIELD TESTS	
		Number of Bugs	Per Cent Control	Number of Bugs	Per Cent Control
Derris Extract *Ivory Soap*	1/200 1-50*	81	100	101	91
Ivory Soap	1-50*	68	100	72	53
Stantex R *Red "A" Soap*	1/50 1/200	69	87	119	92
Stantex R *Red "A" Soap*	1/100 1/200	107	82	101	79
Cubé *SS-3*	4-50* 1/200	98	93	106	72
Cubé-*Pyrolene*	1/200	79	93	106	48
Cubé powder	6% rotenone	80	100	99	96
Cubé-talc	0.75% rotenone	126	55	114	83
Check	—	75	0	75	0

* Proportions by weight.

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STANDARDIZED quarantines relating to the phony peach disease were revised in February, 1939, by Alabama and Illinois. Oklahoma and Maryland were eliminated from the list of infected states, in accordance with the provision for such removal after a three-year disease-free period.

Broadening the Field of Usefulness of Applied Entomology

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There is nothing new in the statement that applied entomology started and developed in the United States chiefly in connection with the production of crops which are used for food or clothing. It is here repeated so that attention may be again focused upon this fact.

At the start of this nation and for a long time after, ours was essentially and necessarily a farming population. The ravages of insects and diseases against the crops which it was necessary and difficult to produce early demanded curtailment. As plantings increased in acreage and variety, to keep pace with an ever growing population, and as native insects and imported pests adapted themselves to our food crops, agriculture, the basic industry, required the giving of more and more attention to pest control. It was only natural, therefore, that when the U. S. Department of Agriculture and the state agricultural colleges and experiment stations were established, agricultural entomology should have received early consideration. Because of the growing and insistent demands of an increasingly specialized agriculture and its consequent increased support of official research institutions, entomologists as well as plant pathologists have been trained largely for work in federal and state supported agencies. In these the problems of the farm and ranch have held the largest place.

As city populations have grown with the increase of manufacture and industry, other problems relating to the control of insects have arisen which in turn have demanded attention, although they are of later origin than those in the field of agricultural production. With the progress of time the entomologist has applied himself to these matters and public moneys have been appropriated to some extent looking toward their solution.

Commercial Fields.—Now it is to be pointed out again that up to a certain time research and other activities in professional entomology were carried on mostly by officially supported workers, and this is true for the most part even today. As insecticides for the control of injurious insects and plant diseases were developed private businesses began to be organized for their manufacture and sale, gradually replacing the home- or farm-made formulae. In time such businesses began to see the necessity of employing their own trained men to assist them to increase sales and to open up wider fields for the use of their products as well as to develop new and better ones. Thus came into being the commercial or non-official entomologist.

As is known to all of us, however, entomologists or those with good training in entomology and related subjects are coming to find use for their knowledge in not only the agricultural insecticide industry but in other private enterprise as well. Nevertheless, this is a comparatively undeveloped field as yet. In it as time goes on there lies, and of necessity there must lie, the greatest opportunity for increasing the service to society by entomology and for expanding the present number of workers in our profession.

I wish first to try to indicate briefly to the entomologists who are charged with the teaching of students as well as to those others who are practicing their profession in its several branches, something of the breadth of the field of commercial enterprises in their relation to entomology. It is felt that the first step in an attempt to broaden the usefulness of applied entomology is to try to arouse the profession itself to a larger conception of the scope of its opportunities. If this can be accomplished to a sufficient extent, it may then be considered worth while to organize for advanced students of applied entomology information which will present to them a rather detailed survey of the whole field of their possible future activities as far as we can see it now.

We live today in a world which is changing with ever increasing rapidity in the complexity of its social, industrial and economic aspects. Insects are almost everywhere and their activities affect us all in more ways now than ever before. If we, as a profession, are to take leadership and to keep in the front in a more industrialized and more specialized world we must become more fully conscious, especially in our larger training and re-

search centers, of the widening opportunities for entomologists to serve business and industry as well as to help in the production of crops and of farm animals. Chemistry has been successful in this to a marked degree.

In the recent past, entomologists have been active in their attempts to cooperate with and also to enter the commercial field and to envisage their broader usefulness to industry. As partial evidence of this several significant papers have been presented to this association dealing with the relation of entomologists to business in the broad sense and analyzing some of the training, personal qualities and special viewpoints necessary to the success of those who would contact this field. Nevertheless most applied entomologists still find their employment in official institutions which are organized largely around agricultural production of some kind. Courses in applied entomology n even our leading institutions quite naturally, therefore, still stress this type of training. It is time, however, to give more serious consideration to broadening the viewpoint of the student who intends to make applied entomology his life-work, opening up to him a wider horizon of his possible field of activity by placing at his disposal during his training period certain information to this end which he is now able to obtain in only a limited way, if at all.

It is indeed helpful for those with broad experience to point out in an occasional paper the necessity for entomologists to make wider use of their opportunities for service, but such efforts can be little more than highly suggestive at best, and they leave both the profession and the student in somewhat the same position as before. Without more concrete information than is now presented to him as to how he may better fit himself to enter and develop the more unorthodox fields of activity, the individual is still lacking the best possible preparation to do so. It is also felt that those who will take up official institutional work should benefit equally by a more complete conception of the commercial field in order that they may better cooperate with its representatives and understand its problems. The writer has in preparation a rather detailed outline of the commercial activities for entomologists which it is hoped might form the basis for a special course for advanced students in some institution.

AGRICULTURAL INSECTICIDE INDUSTRY.—The agricultural insecticide industry would seem to be the most promising and immediate field in which applied entomology could further increase its usefulness. This is because of the size and importance of this business in the public economy and its inherent close relation to insect activities. Dr. R. C. Roark has recently estimated that the retail cost of insecticides and fungicides sold annually in the United States is probably not less than $100,000,000. For various reasons the probable correct total is difficult to arrive at, but the writer ventures to state that this figure is too low. Although the annual probable damage caused by insects of around two billion dollars is by no means entirely susceptible to reduction by insecticides, chemical control is still one of our most widely used and most effective weapons against the pests of growing crops. The actual size and importance of this industry is but imperfectly understood by most entomologists and a comprehensive analysis of the workings and the problems of this business and of its relations to the profession would be of value to those who desire to broaden their field of service.

Although most of the leading nationally or semi-nationally advertised agricultural insecticide concerns have by now come to employ trained entomologists to assist them with their experimental, educational and sales development programs, there are frequently even yet but few such individuals in each firm. Many smaller and more localized insecticide manufacturers should be able to profit by the addition of trained men to their staffs.

Even though in most cases the sales force, from the sales manager on down through district managers and salesmen, are better fitted technically for specialized insecticide sales work than formerly, it is still not too common to find individuals in such positions who have had thorough training in entomology, plant pathology and related subjects. Other things being equal, men with such training and knowledge make better salesmen than those without it. The best type of insecticide salesman is far more than just an order-getter who is a good talker and who can

outfigure his competitors on price and terms. He is constantly called upon by his jobbers and dealers to give them sound advice and suggestions both as to the uses of his particular products and as to pest control in general. Such service has often swung an order or a contract to the firm which is equipped to give it. As the demand for better pest control has increased, competition by firms having either service or materials to sell has become keener. Research, however, as well as both business and manufacturing efficiency, has tended to bring quality and prices more into competitive line, and technical knowledge, when combined with experience, has become more of a factor in the getting and holding of business.

Enormous losses are annually suffered by the large industries handling stored grains and other stored products, including tobacco, in warehouses. Although considerable attention has been paid by official workers to the reduction of such losses, most entomologists have but little real working knowledge of large-scale fumigation or other control measures for the insects affecting such products under commercial conditions. A better understanding of the size, importance and insect problems of this group of industries might well fit more entomologists to obtain employment in it to the benefit of both industry and entomologists.

The rapid growth of the fruit and vegetable canning industry and especially more lately of the frozen vegetable business, has increased the necessity for more effective pest control on the increasing number of crops which are marketed in such ways. Only the products as free as possible from insect and disease blemishes can find a profitable market when sold in such a manner. Even where vegetables are grown on contract by many individual farmers to supply large processing or canning plants, canning companies and the like might well be made to see the value of specially trained entomologists and plant pathologists in directing the large scale pest control operations involved. This field has as yet been entered and developed to but a limited extent. The organization and the special problems of the canning and frozen food industries should receive more detailed attention by students of pest control.

PEST CONTROL.—Although considerable attention has been paid by official entomologists to the development of measures for the control of household insects the emphasis has usually here been placed on what the individual home owner or tenant should do. The most important problems in this field are, however, in the larger towns and cities, together with their suburban areas, and these can be satisfactorily handled only by trained exterminators and not by the individual occupants. Few students of entomology are as yet able to gain a satisfactory idea of the practical application of control measures which are employed against household insects under city and suburban conditions. This situation has recently, however, begun to improve. Insect control, it should be emphasized, in factories, bakeries, office buildings and public institutions requires a different technique from that practiced in the home.

Sensing the growing possibilities for business along this line there has developed a large number of professional exterminators operating in and near the larger cities. Some exterminating concerns have a sizable staff of operators, up to 100 or even more, who make the actual inspections and treatments and several of these firms have branches in various cities. There are said to be over 1,000 exterminating firms in the United States, and the total amount of money collected annually on regular contracts and on special treatments would surely impress entomologists with the considerable size of this business were the actual amount more accurately and widely known. It has been estimated to approximate 50 million dollars.

Although there have been in the past many ignorant and unscrupulous exterminators, the progressive and intelligent firms have been recently making a determined effort to raise the standards of their work and of their profession. The National Pest Control Association now has regional branches and a membership of about 400. Its unofficial organ *Pests*, formerly *The Exterminators' Log*, now in its sixth volume, carries an increasing number of authoritative articles pertinent to its subject-matter field. A most progressive step by all concerned is the recently instituted annual clinics for exterminators held at Purdue University.

These clinics have been well attended. A further good step is the active interest our association is now taking in this considerable business which is so important to the public welfare, especially in our larger towns and cities. The devotion of one-quarter of the program of this branch meeting to household insects, with all local exterminators invited to attend, is a concrete evidence of leadership in applied entomology and of its desire to help improve an important and essential industry.

Even as yet exterminators include in their number but few persons with basic training. The gap between theory and practice in this field is a wide one to bridge, and considerable business training and experience are essential to success. As time goes on it is hoped that entomologists may be better able to train themselves to enter this work to the benefit of the legitimate operators.

It should next be stated that the manufacture and sale of household insecticides and cattle-fly sprays, especially of the pyrethrum and rotenone type, are a more considerable business than is generally appreciated by most entomologists. Its highly specialized problems of manufacture, quality control and distribution must be better understood by entomologists if they are to assist this industry to a greater appreciation of its importance to the public. Several entomologists are now employed in connection with this phase of the insecticide business.

Around the fumigation of buildings, grains and other stored products, as well as of citrus fruits in California, have grown several large businesses, the problems of which are primarily entomological in their nature. We should become better informed as to the workings of such activities and the regulations under which they operate in order that we may open up opportunities for wider service in this field.

In recent years there has been a growing use of airplanes for the application of insecticide dusts and sprays and the practicability of this method of crop pest control under many conditions has by now been well established. Most of the firms or individuals operating planes for this purpose are basically unacquainted with agricultural operations, the grower usually supplying the insecticides and determining the dosage and timing of the applications and paying a fixed charge to the operator per pound or gallon or per acre. One of the largest airplane dusting firms, however, has a large fleet of standardized planes, and their operation is directed by an experienced entomologist who has several technically trained assistants. Other like firms should be able to use the services of pest control specialists, and there is undoubtedly opportunity for entomologists with the proper training and experience and with some capital to exploit this promising field.

CONSULTING ENTOMOLOGISTS. — The matter of private practice as a "plant doctor" has been little considered as yet. Professor H. H. Whetzel of Cornell University has, in recent years, been the chief advocate of such an activity. He claims there is room for a thousand "plant doctors" in the United States operating in cities of about 2,000 population and larger if young men with the proper training and personal characteristics, having natural sales ability and some capital to start out on, would undertake to develop this field. The object would be to perform the actual control operations required by the home or estate owner. Tree experts are of course more or less in this same category but they usually operate as groups rather than as individuals or pairs working in restricted localities. Here again, however, is an opportunity for extending entomological activities.

Following the success of consulting chemists and consulting engineers, consulting entomologists have long been talked about and a few well trained men have actually gone into this type of work. Although they have met with some success no service of this kind has as yet been developed in any way comparable to that conducted by trained chemists or engineers or psychologists. This may be due to the newness of our profession, the breadth of the field to be encompassed or to the considerable support of public institutions organized for pest control and insecticide research. Also industrial fellowships may have filled this need to a considerable extent. There may be certain inherent difficulties which have delayed the development of more consulting entomologists, but it is believed that the day will come when a group of qualified individuals will organize privately in some

manner so as to make worth-while contributions to agricultural and industrial research and practice and at the same time make a dignified and substantial living.

ADVANCED COURSE IN PRACTICAL ENTOMOLOGY.—It is hoped that the above sketch will be suggestive of the possibilities in little developed or neglected fields of activity in which applied entomology could be of greater service. It is suggested, however, that a course should be developed in at least one of our leading departments to give advanced students of applied entomology this information in much more detail, enabling them to have a better understanding of the problems, products and activities of such businesses than they are now able to obtain. Although the number of available men qualified by training and experience to organize and present such subject matter adequately is necessarily very limited, I believe that if the experiment were tried it would establish a progressive step in the training of entomologists.

Briefly, I would have in mind for example, an analysis of the whole insecticide industry as to its size and importance, the origin and manufacture of its products, its sales and distribution problems, its legal aspects (patents, label requirements, insecticide laws) and its present research and control set-up; in short, those phases of the industry it would seem advisable for entomologists to know more about. Such information is now presented in its entirety in none of our colleges so far as I am aware. This same treatment should be extended to the other businesses and industries under consideration with the necessary variations in subject matter and emphasis.

Advanced students of applied entomology undoubtedly now learn in our more specialized departments, at least, the principles of reducing insect populations and the general means of utilizing these and of determining the results obtained. Much time and trouble could be saved them if they could be further oriented as to the more practical uses of such knowledge, irrespective of whether they find their work in either the official or the commercial field.

Such information as a more detailed idea of crop growing regions and of crop seasons in relation to the limits placed upon production by commercial losses from diseases and insects would be useful. Regional variation in pest control schedules should be thoroughly taken up. The plan and workings of research activities and organizations, such as the Crop Protection Institute, and of industrial fellowships in general might be explained, as well as of the manufacturing and trade organizations operating in the field under consideration. Extracurricular activities to develop leadership and alertness should be encouraged, and those qualities and actions likely to make for success in business contacts should be analyzed.

These are only a few of the elements of such a course and are given here merely to indicate the nature of its composition. The subject is a considerable one. It takes in many things not strictly in the field of entomology but which are intimately related to it. I am told that the psychologists in some of their courses in applied psychology outline in a rather detailed way the whole scope of this field, which is largely commercial, and analyze the principal businesses and industries which absorb at least 25 per cent of their profession. Even though it is doubtful if 10 per cent of all the entomologists are as yet engaged in private rather than official work, it is believed that we too should start to give at least some of our serious students an adequate conception of a broader field of service and of livelihood.

A leading national authority on business and industry recently stated that one of the keynotes of economic development is industrial research. He said that over 2,000 concerns in the United States now maintain research laboratories, evidence of the importance which is attached to specialized technical effort when it is focused on the particular problems of various types of business. Entomology and plant pathology are undoubtedly included in this number, but unquestionally both should constitute a larger proportion than they now do. The fact that much of our work must be done in the field as well as in the laboratory makes it none the less technical research in the true sense of the term.

It is hoped that by gaining a clearer conception of our opportunities for greater service, by developing a somewhat more comprehensive course of instruction for advanced students and by making a steady increase in the actual participation

in business and industry by trained entomologists, we shall be able to command increasing support from public agencies and private enterprises for more extensive research in pest control and for its wider practical application.—11-18-38.

The Element of Timing in Relation to Pea Aphid Control*

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In the 30 or 40 years that the pea aphid has been with us as a major pest practically nothing of a permanent nature has been developed in the way of control, until during the past four or five years. Just how permanent some of the more recent developments in pea aphid control are likely to be is certainly open to question, but during this comparatively short time a vast amount of effort has been expended and truly remarkable progress has been made not only in the development of insecticides but, what is just as important, in the perfection of machinery adapted to applying these under field conditions.

As things now stand there are perhaps four or five methods of control available to the canner. While some of these are obviously of more practical application than others, any of them, if properly used, can be counted on to kill the pea aphid. Unfortunately, the general problem of pea aphid control is so involved and the factors that may influence the results are so numerous and so difficult to control that when it comes to measuring the results from a financial point of view we find that there is much more to the problem than that of merely killing the insect.

Those who have followed the pea aphid situation closely during the past few years and have had a chance to observe at first hand the large scale operations that have been carried out by the pea canning interests of the country in fighting the insect must have been impressed by the seemingly hopeless confusion and uncertainty that has all too often characterized such campaigns. Needless to say, such a condition has often resulted in a vast amount of wasted effort, unnecessary expense and bitter disappointment. While this situation has resulted in many cases from the use of improper methods of control or from the inefficient handling of otherwise effective ones, the trouble in no small measure has unquestionably resulted from a lack of understanding on the part of the canner of a few fundamental factors bearing on the pest he is trying to control, and above all from the fact that he has had no practical way of measuring an aphid infestation or of determining with any degree of accuracy when control operations should be commenced or when, as is frequently just as important, these may not be warranted at all.

In the present discussion we by no means presume to suggest a final answer to the question of timing as applied to pea aphid control. This is altogether too difficult and involved a problem to be disposed of so easily. The object we have in mind is to outline briefly an example of the typical field studies we have attempted to carry out in the course of the past three or four seasons, which bear directly on this aspect of the pea aphid control problem, and to offer the canner a method of measuring the intensity of an aphid infestation—a method that while admittedly crude, should, if intelligently carried out, give him a much clearer picture of the problem he is facing and should at the same time enable him to apply whatever control program he may adopt in a more logical fashion and with less waste and confusion than in the past.

On account of the uncertainty that has so often been associated with attempts by canners generally to control the pea aphid, we have had in mind for some time the working out of a simple, practical method for measuring the intensity of an infestation that the average canner would be both able and willing to use. What we have aimed at is a method that will give the canner a clear picture of what is actually taking place in the territory under his control, so that he will be in a position to plan and carry out his control

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operations with more confidence and with a better chance of success than in the past.

The method we have finally adopted, not only for the canner but also for our own use in checking on our own field work, while not necessarily the best or the most accurate, has been found exact enough for all practical purposes if used intelligently, and is so simple to carry out and interpret that any canner should be able to make use of it with but little expense and without disrupting in any way his established routine. Briefly, this method comprises two distinct operations: a field collection made by the use of a standard beating net, to be repeated at intervals throughout the season, and counts of the aphids that are collected in this way to serve as a background for use in planning and carrying out whatever control program may be adopted.

FIELD COLLECTIONS.—The unit we have adopted for use in all cases is the number of aphids of all sizes taken in 10 strokes of a standard beating net. The net that is being used is one approximately 11 inches in diameter at the mouth and 20 inches deep, tapering slightly toward the bottom, the bag being made of heavy cotton drilling. The handle is 24 inches long. We prefer a somewhat longer handle, but have adopted this length as a compromise for the convenience it affords the field man in transporting and handling the net.

As to construction, the frame of the net is made of a one-half inch iron pipe coupling to which is attached a ring made of 9-gauge spring steel wire or of 8-gauge or even 6-gauge wire in case iron wire has to be used. The base of this ring is firmly wired to the coupling by means of 14-gauge soft iron wire, after which the whole is thoroughly soldered. The iron binding wire should be continued beyond the shoulders of the ring before soldering for if this is not done the net will eventually break at this point under the hard usage it is sure to receive. The wooden handle is attached by simply threading it directly into the iron coupling. Such nets may be made in the machine shop of the canning factory at a very nominal cost.

In making the field collections it is well to have them all taken by the same man in any given territory for the entire season. This is desirable since there is apt to be some variation in the collections made by different men, depending on such factors as the height of the man, the force with which the net is driven through the peas and on how deep it is buried as it is swung through the vines.

To insure the greatest possible uniformity in the records there should be some one experienced man in each organization responsible for instructing the field men in the technique of making the collections. By occasional checks on these field men through counts of collections taken by them under identical conditions, any serious inequalities can readily be corrected. Unless some effort is made, however, to see that the different individuals make their collections in approximately the same way the counts may not be uniform enough to make accurate comparisons possible.

Ordinarily but a single collection is made in each field, the operator walking into the peas 100 feet or more before commencing to sweep. Subsequent collections to be comparable should be made in approximately the same general locality.

The essential equipment for making the field collections is relatively simple, consisting as it does merely of the net, a supply of 10-pound paper bags and a small bottle of granular calcium cyanide. After sweeping, the operator transfers the contents of the net to one of the paper bags, adds a small quantity (from one-half to 1 gram) of the cyanide to kill the insects and facilitate counting, and closes the bag by merely twisting the top tightly, a procedure found more satisfactory than folding over the top of the bag.

The entire operation of making a collection in this way requires only three or four minutes at the outside, and in general the average field man can make such collections in the course of his regular inspection trips without their working any particular hardship on him or interfering seriously with his regular routine. In order to insure comparable results, collections should be made only when the plants are relatively dry.

COUNTING.—The actual counting should be made by individuals selected especially for this work, and the counts should be completed the evening of the day the collections are made so that the records may be available at the office the following morning. The counting tech-

nique is almost as simple and as readily carried out as that of collecting. Obviously when there may be as many as 20 to 40 thousand aphids or more in a single lot it is not practicable to do much direct counting.

The procedure that is followed in practice is to deposit the dead aphids from

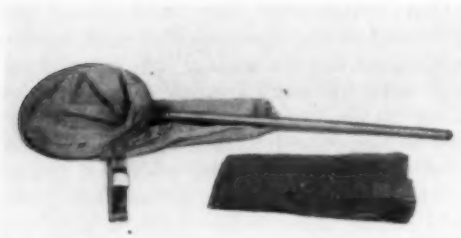

FIG. 1.—Essential equipment for making field collections of the pea aphid: beating net, supply of 10-pound paper bags and calcium cyanide.

the bag on a smooth surface. The mass of aphids is then divided and subdivided by means of a thin-bladed, straight-edged knife until it is reduced to a group containing 200 to 300 individuals. A detailed count is then made of these and the results used as a basis for computing the number in the original lot. Such a procedure must, at first, seem hopelessly crude and inaccurate to those who are not familiar with the method. Actually, if the work is carefully done, particularly where two individuals are working together and have to agree on the relative size of the groups as each subdivision is made, it will be found that the method is surprisingly accurate, as can readily be demonstrated by occasionally checking records secured in this way by counts made of the entire lot. Unquestionably, counts secured in this way are accurate enough for all practical purposes; certainly for any use to which the canner is likely to put them. The chief source of error in this method will be found not in the system of counting just described but in the field sampling, and for this reason every effort should be made by means of careful instruction and by repeatedly checking the men making the field collection to guard against any flagrant discrepancies from this source.

The equipment that will be found essential in making the field collections as well as in the final counting is shown in figs. 1 and 2 and consist, as has already been said, of a net, a supply of 10-pound paper bags and a bottle of calcium cyanide for the field work, a magnifying glass, preferably one magnifying three or four diameters, a long, thin-bladed, straight-edged knife, a pair of forceps and a small needle-knife to use in separating the aphids when making the counts. Such population records are, of course, all very interesting in themselves, but the thought which naturally occurs to one is this: What good are they to the canner and what is he going to do with them after he gets them?

Here are some of the things such population records, if consistently kept throughout the season, should do for the canner. Instead of the hopeless fog of uncertainty that has commonly surrounded the men at headquarters who are supposedly directing the pea aphid control operations, these men have before them an exact picture each day, or every few days at least, of what is happening in each field in any particular territory for which they are responsible and they are

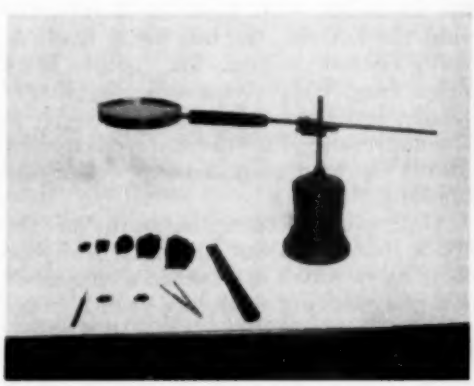

FIG. 2.—Articles that will be found helpful in making systematic population counts: magnifying glass, thin, straight-edged knife, forceps and needle knife.

in a position to know better even than the field operators themselves what is taking place each day and what the next logical move should be. In addition, since counts should be available both before and after all control measures are applied, it is possible for them by the use of such records to detect and correct without loss of valuable time any mistakes or failures that may have occurred in the course of the field operations, situations that

Table 1.—Aphid population in relation to crop damage of peas. A gauge to be used by the canner in interpreting the results of records based on systematic field counts of the pea aphid.

HEIGHT OF PLANTS	DEGREE OF INFESTATION BY APHIDS				
	Trace	Slight	Moderate	Severe	Ruined
Small, 1–6 inches	1–25	25–100	100–300	300–1,000	1,000–4,000
Medium, 6–12 inches	25–100	100–300	300–1,000	1,000–4,000	4,000–10,000
Large, over 12 inches	100–300	300–1,000	1,000–4,000	4,000–10,000	10,000–50,000

otherwise are usually discovered too late to remedy.

By determining beforehand (see table 1) how far an infestation should be allowed to develop before control operations are started it may often be possible to avoid the trouble and expense of treating; or at least a considerable part of the acreage may perhaps be eliminated in this way. This is particularly apt to apply when a careful record has been kept of the course of the infestation from the beginning of the season, for when the aphid population in a field has reached the danger point, as indicated by a study of table 1, there is a vast difference in the procedure called for, depending on whether the counts show the population to be increasing rapidly, merely holding its own, or perhaps actually starting what may develop into one of those spectacular declines that are so familar to all who have followed the pea aphid closely in the field. Without frequent field counts such a situation is ordinarily not detected until it has been under way for some time and perhaps needless expense incurred in the carrying out of uncalled-for control measures.

It must also be obvious to anyone familiar with the pea aphid problem that a complete record taken in this way should, if continued for a number of seasons and under different growing conditions, prove an invaluable guide to the canner possessing them as an aid in planning future control operations. A series of annual records such as this should go far in enabling him to look ahead and predict, as clearly as such a thing can be done, what the aphid is likely to do in any particular season and under the weather conditions prevailing at that time. Records of this sort, if consistently kept, would provide him with reliable information for his guidance in the future that he could not hope to get from any other source.

As a means of interpreting and applying the information furnished by such a systematic series of population counts, table 1 is offered as a rough guide. This table is necessarily crude and is, of course, subject to revision; but it is by no means wholly arbitrary for it reflects information gathered from observations and field experiments during the past three or four seasons bearing on this point. While certainly not infallible, this table or some

Table 2.—Relation of aphid population to yield of peas. This table shows the yield from 10 typica pea fields covering the seasons 1936–1938 in relation to the aphid count and the intensity of the infestation as based on table 1. The aphid counts recorded represent the peak of the infestation in all cases. General growing conditions during 1936 were much more severe than in either 1937 or 1938, as is reflected in the yields.

FIELD	SEASON	APHID COUNT	INTENSITY OF INFESTATION		YIELD (Pounds Per Acre)
1	1936	2,440	Moderate	1,000– 4,000	848
2	1936	12,056	Ruined	10,000–50,000	12
3	1936	22,000	Ruined	10,000–50,000	446
4	1936	27,876	Ruined	10,000–50,000	226
5	1936	64,000	Ruined	10,000–50,000	6
6	1937	6,248	Severe	4,000–10,000	1,707
7	1937	16,856	Ruined	10,000–50,000	924
8	1938	1,744	Moderate	1,000– 4,000	1,587
9	1938	625	Slight	300– 1,000	2,995
10	1938	4,352	Severe	4,000–10,000	1,100

modification of it, we feel confident, will be found exceedingly helpful as a gauge to be used by the canner in judging the seriousness of any infestation he may encounter and the procedure he should logically follow in dealing with it.

A study of the field records that are given in tables 2 and 4 should prove of interest to the reader as bearing on table 1, representing, as they do, a few of the fields in which periodical population counts were made and checked against the yields at the end of the season. Space will not permit any lengthy discussion of these records, but the reader may find them of interest as bearing on table 1 and the manner in which it was built up.

Table 3.—Suggested plan for timing experiments as applied to pea aphid control studies.

SECTION	PLAT	TIMES TREATED	DATE OF TREATMENT
1	1	1	June 1
	2	2	June 1, 7
	3	3	June 1, 7, 14
	4	4	June 1, 7, 14, 21
	5	5	June 1, 7, 14, 21, 28
2	6	1	June 7
	7	2	June 7, 14
	8	3	June 7, 14, 21
	9	4	June 7, 14, 21, 28
3	10	1	June 14
	11	2	June 14, 21
	12	3	June 14, 21, 28
4	13	1	June 21
	14	2	June 21, 28
5	15	1	June 28
6	Check	—	—

As has already been pointed out, the pea aphid problem is complicated by many factors over which the canner has little or no control, such as variations in temperature, rainfall and fertility, the occurrence of pea diseases as well as the prevalence of diseases of the insect itself, with the resulting decrease in vigor of the aphid population as a whole, to say nothing of other natural checks on the aphid. For this reason it is too much to expect any system such as the one we have just outlined to apply with equal force under all the conditions that may be encountered in a pea planting. The canner who plans to make use of this method must therefore recognize that a certain amount of judgment and experience will be called for in interpreting his findings if the method is to prove as helpful to him as it should, and naturally the longer the method is used the more valuable the records it will supply should become to him.

FIELD EXPERIMENTS HAVING TO DO WITH TIMING.—In addition to the indirect method of approaching the problem of timing that has just been outlined, the results secured in this way should become particularly significant if supplemented by occasional direct field experiments carried out in general according to the plan outlined in table 3. In this hypothetical experiment a total of five applications is provided for. Probably a smaller number would be sufficient with a short season crop such as peas, but five are called for here since this number would probably be necessary to clear up such disputed points as those growing out of the so-called residual action of certain insecticides where, as has sometimes been claimed, they may be counted on to protect the pea crop for the entire season, even when applied while the plants are small. In such a case a series of at least four or five applications, representing 10 and 15 plats, respectively, might be re-

Table 4.—Relation of aphid population to yield of peas (1,100 pounds per acre). This record shows a few of the periodical aphid counts as made in a typical field of Perfection peas in 1938 and illustrates the fluctuation in the aphid population that so frequently occurs.

DATE	HEIGHT OF PLANTS	APHID COUNT	INTENSITY OF INFESTATION	
June 4	5 inches	269	Moderate	100– 300
June 10	9 inches	754	Moderate	300– 1,000
June 17	14 inches	2,152	Moderate	1,000– 4,000
June 21	18 inches	4,352	Severe	4,000–10,000
June 30	20 inches	435	Slight	300– 1,000
July 4	24 inches	1,664	Moderate	1,000– 4,000
July 9	25 inches	2,176	Moderate	1,000– 4,000

quired, although in general a series based on a total of three applications would probably furnish all essential information.

After experiencing the uncertainty that has so often accompanied any serious attempt to apply control measures for the pea aphid at the most effective time, the canner may find that a glance at this suggested schedule will show how the information it should supply may be expected to clarify the situation, for it should be apparent that there are few direct questions bearing on the problem of timing that could not be answered by an experimental set-up such as this if properly carried out.

In the example given in table 3, it will be seen that all five plats in Section 1 are treated on June 1. On June 7, Plats 2 to 5 inclusive of Section 1 and all of Section 2 are treated, omitting Plat 1 of Section 1. On June 14, Plats 1 and 2 of Section 1 and Plat 1 of Section 2 are omitted, while the remaining plats of these two sections are treated as well as all the plats in Section 3. In this way it will be seen that one new plat is dropped each week from each section that has been treated the preceding week and one entire new section taken on for treatment; the plan proceeds in this way until at the end of the period only the last plat in each section receives an application. This system has been applied whenever possible in the course of our field studies during the past two or three seasons. The results of one such typical experiment are shown in table 5. It is given here merely to serve as an example of the method used in this approach to the problem and to indicate what may be expected from such an experiment is supplying the answer to such questions as the most logical time to commence control operations, the number of applications that may be expected to give the greatest commercial return, as well as the increase or perhaps the loss that may be counted on from deferred applications made after the optimum period for treating has been passed.

This example, table 5, represents one of the fields treated in 1936 in accordance with the system in question, the nicotine vapo-fumer being the method of control used. In this field the first application was made on June 10, approximately 10 days before blossoming of the peas. The second application was put on June 19, at which time the peas were beginning to bloom. The third treatment was made June 29, about two weeks before harvest. As may be seen, table 5 Plat 1 represents a single early application made approximately 10 days before bloom. Plat 2 received this early application and another on June 19; Plat 3 received all three applications, on June 10, 19 and 29, respectively. Plat 4, on the other hand, received but a single treatment 10 days later than Plat 1, while Plat 5 received this deferred application as well as the last in the series. Plat 6 got but a single late application two weeks after the first of the series was applied.

Table 5.—An experiment in timing as applied to pea aphid control. This experiment, which included a 3-acre field of Perfection peas, was carried out during 1936 according to the general plan outlined in table 4 except that here a total of three applications only was made. The object in mind was primarily to throw some light on the proper time to start control operations, the value of repeated applications, and the limit beyond which control operations might not be warranted.

PLAT	TIME OF TREATMENT	APHIDS PRESENT (July 8)	YIELD (Pounds per Acre)
1	June 10	1,904	668
2	June 10, 19	532	998
3	June 10, 19, 29	31	1,239
4	June 19	608	895
5	June 19, 29	70	1,101
6	June 29	416	761
7	Check—untreated	27,876	226

Table 5 summarizes the results of this experiment, showing not only the sequence in which the applications were made but the total yield for each plat, as well as the aphid count in each case, made on July 8, five days before harvest. It should be noted that this particular field, comprising three acres of the Perfection variety, was treated during the excessively hot, dry season of 1936, and the unfavorable growing conditions that prevailed unquestionably aggravated the damage caused by the insect. While the results of this one experiment are interesting, suggesting among other things the danger of starting control operations too soon, several such series, replicated and preferably carried out during different seasons, might be needed before any far-

reaching generalizations would be warranted. It is given here merely as an example of the method used in approaching the problem of timing from this angle. This method, if carried out consistently for several seasons or under a variety of growing conditions, should provide an answer to almost any direct question that might come up in regard to timing. While the procedure followed in carrying this method through in the field may seem cumbersome and involved, in reality it is simple once the routine is established. It would unquestionably be well worth the while of any pea canner interested in aphid control to have at least one field in his territory treated in this way for his own guidance. The cost would be very small in relation to the value of the information supplied by it.—11-18-38.

Toxicity Studies of So-Called "Inert" Materials With the Bean Weevil, *Acanthoscelides obtectus* (Say)*

SHIN FOON CHIU, *Cornell University, Ithaca, N. Y.*

Laboratory experiments have demonstrated that certain so-called "inert" materials, when used as dusts, are definitely toxic to a number of insects infesting stored products. The present work was undertaken to study the toxicity† of some of these "inert" materials and their physiological mode of action upon the bean weevil, *Acanthoscelides obtectus* (Say). The initiation of this work was mainly due to the interesting toxicological experiments made by Maxwell (1937) who found that aluminum silicate clay and lime were highly toxic to the hairy chinch bug, *Blissus hirtus* Montd., when applied under dry conditions.

MATERIALS.—Six chemically inert dusts, one of organic origin and five of inorganic, were used in the experiment. These materials are often employed as carriers for potent insecticides such as nicotine, rotenone, arsenic and fluorine compounds. A brief description of each of the dusts used follows:

Crystalline Silica.—This is a kind of very finely ground sand. It consists of about 98 per cent silicon dioxide, 0.2 per cent moisture and a small amount of aluminum, iron, calcium and magnesium salts. It is a white powder, weighing about 57 pounds per cubic foot, and has a specific gravity of 2.68. The shapes of the particles are rather irregular. With the exception of the extremely small ones, most of the particles are sharp-edged. The particle sizes range from 1 to 147 microns and average (in terms of surface) 2.9 microns in diameter. From the results of hydrometer analysis, 37 per cent (by weight) of this material is below 10 microns in diameter (see fig. 2, the curve for extra fine crystalline silica). The particles are easily separated and do not tend to form aggregates. (*Naaki*, furnished by the Agricultural Insect Destruction Corporation.)

Amorphous Silica.—This is a form of siliceous earth obtained from diatoms. It contains 93–95 per cent of silicon dioxide and a small amount of iron, aluminum and other impurities. Due to the presence of a small amount of soluble sodium salt, it is slightly alkaline in reaction. The material is light buff in color and is very light and bulky, weighing only 8 pounds per cubic foot. Its specific gravity is 2.31. The particles are round and porous, having considerable so-called "internal surface." From the results of hydrometer analysis, all the particles are below 15 microns in diameter, and 98 per cent (by weight) of the material consists of particles under 10 microns in diameter. (*Celite*, supplied by the Johns-Manville Research Laboratories.)

Magnesium Carbonate.—This is a U.S.P. grade light powder, a light bulky material, the particles tending to form aggregates, particularly when wet. The particles are

* The author is greatly indebted to Professors T. Roy Hansberry and G. F. MacLeod for their helpful suggestions and criticisms. Thanks are due to Dr. Henry Menusan, Jr. for his cooperation in the respiration studies.

† The term toxicity, as used in this paper, does not imply any chemical reaction.

round, and quite uniform in size, ranging from 1 to 3 microns in diameter.

Bentonite.—This is a clay of volcanic origin, mined in Wyoming. It consists of 98 per cent pure bentonite or montmorillonite which has the approximate chemical formula:

$$H_2O \cdot (Al_2O_3, Fe_2O_3, 3MgO) \cdot 4SiO_2 + nH_2O$$

This material was sifted through a 400-mesh screen and 90 per cent of the particles were less than 10 microns in diameter. It has a specific gravity of 2.75 and weighs about 40 pounds per cubic foot. The shape of the particles is roughly spherical, and the material tends to form aggregates. It is readily dispersed in water and settles out of the suspension very slowly. (*Volclay Bentonite BC Grade A*, supplied by the American Colloid Co.)

Talc.—A hydrous silicate of magnesia ($H_2Mg_3Si_4O_{12}$), soft with a soapy feel, sometimes called soapstone. It contains about 60 per cent silicon dioxide, 30 per cent magnesium oxide and a small amount of aluminum and ferric oxide. The material was supplied by the Insecticide Division, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. The particles are flat, irregular in shape and range from 3 to 9 microns in diameter.

Walnut Shell Flour.—This dust is made of pulverized walnut shells, produced and ground in California. It contains about 60 per cent cellulose, 30 per cent lignin, 4 per cent cutin and 4 per cent moisture. The flour is yellowish brown in color, light but not bulky. The shape of the particles is nearly spherical. The material used was sifted through a 200-mesh screen, the particle-sizes ranged from 1 to 66 microns in diameter. About 35 per cent of the particles are less than 6 microns in diameter. This material was supplied by the Agicide Laboratories.

METHODS.—Because all these "inert" dusts contain a small amount of water and because it has been theorized that these materials have a desiccating effect upon insects, they were thoroughly dried in an oven maintaining 110 degrees C. before being used in the tests.

The insects used in this investigation were reared on red kidney beans, *Phaseolus vulgaris* L., under an environment of 26–27 degrees C. and 65–70 degrees relative humidity. A group of 120 insects two to four days old was placed in a 4 by 7 centimeter narrow-mouthed bottle containing 2 grams of the dust material. The bottle was shaken and rotated gently for one minute so that the insects were coated heavily with the particles of the material. Then they were transferred to a sieve which was shaken slightly to allow the excess dust to drop off. The food, if it was to be dusted, was treated separately in a similar manner. After dusting, the insects were divided into two groups, one with food (generally 6 kidney beans were provided for 20 weevils) and another without food. Ten to 20 insects from each group were placed in a small glass container (4.5 by 3 centimeters) covered with a piece of muslin. Records were taken separately for each container, so that each test was replicated three or six times. Untreated checks with and without food were run with 20 insects taken from the same population as was used for each test. Preliminary experiments indicated that when 60 insects were used for each test, the mean of the days required to produce about 50 per cent net mortality was a statistically accurate and significant measure of toxicity.

By weighing groups of insects before and after being dusted it was found that this method of dusting gave consistent results in the amount of dust adhering to the insects. For a given material the dosage may be considered as constant. The average amount of dust adhering to each weevil was as follows: crystalline silica, 0.47 milligram; amorphous silica, 0.075 milligram; magnesium carbonate, 0.16 milligram; bentonite, 0.09 milligram; talc, 0.11 milligram; walnut shell flour, 0.167 milligram.

Attempts have been made in these experiments to hold constant the factors that would influence the toxicity of the "inert" dusts, so that the material used remained the only variable. In all the tests the insects were kept in the dark, at a temperature of 25–26 degrees C. and a relative humidity of 70–75 per cent. Usually the insects were examined once a day for the first 10 days and on alternate days thereafter. Observations were discontinued after 30 days. An insect was considered dead when it had ceased all body movements and no longer responded to the pressure of a dissecting needle.

The formula of Abbott (1925) was used

Table 1.—Toxicity of amorphous silica to the bean weevil. (No food was provided for the insects.) Per cent mortality in six tests, 10 insects in each test, at specified lengths of time after beginning of tests.

Length of Time, in Days	Test No. 294	295	296	297	298	299	Average*
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	10.0	0.0	0.0	0.0	10.0	0.0	3.3±2.1
6	30.0	0.0	30.0	0.0	20.0	20.0	16.7±5.6
7	55.6	44.4	33.3	44.4	22.2	33.3	38.9±4.8
8	66.7	66.7	77.8	77.8	55.6	44.4	64.8±5.3
9	88.9	66.7	88.9	88.9	55.6	77.8	77.8±5.7
10	100.0	87.5	87.5	87.5	75.0	75.0	85.4±3.8
11	100.0	83.3	100.0	100.0	83.3	100.0	94.4±3.5
12	100.0	100.0	100.0	100.0	100.0	100.0	100.0±0

* The standard error was calculated by Bessel's formula,

$$\frac{S_x}{x} = \sqrt{\frac{Sx^2}{n(n-1)}}$$

for deducting the mortality attributable to natural causes in making calculations of the percentage of mortality. Table 1 presents the statistical treatment of a part of the data. The time-mortality lines were plotted (figs. 1 and 3) according to the method of Bliss (1937) with the ordinates as net percentage of mortality on the basis of probits (probability units) and the abscissas as logarithms of the time of survival after treatment. Probit values corresponding to 0 per cent and 100 per cent kill are not included, except in the case where less than three experimentally determined points were obtained. Under such conditions the 100 per cent mortality is plotted as 99.5 per cent and the slope of the line will have the maximum rather than the mean value. It is believed that the inclusion of this additional point will increase the information obtained from the graphs. The lines in the graphs (figs. 1 and 3) have been fitted by eye to the experimentally determined points. Each point in the graphs represents the mean net percentage of mortality of three samples of 20 insects each or six samples of 10 insects each.

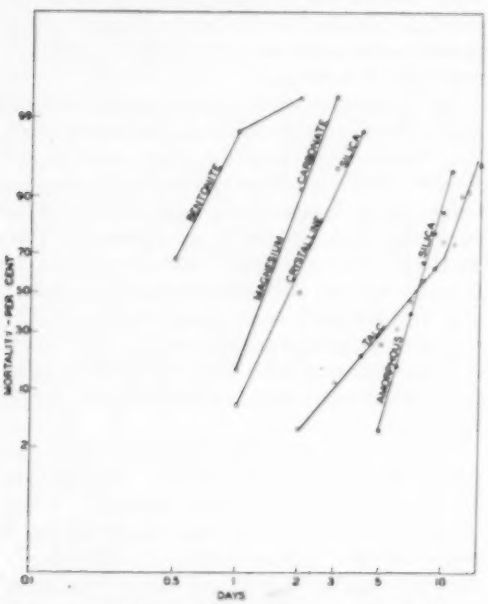

FIG. 1.—Toxicity of different "inert" materials to the bean weevil. No food was provided for the insects.

In evaluating the toxicity of an insecticide, the minimum variation in time or dosage appears at the point of 50 per cent kill. Therefore the time required to kill 50 per cent of the insects, as obtained by interpolation from the time-mortality line, is used as a basis for comparing the toxicity of different dusts and for theoretical studies of the various factors that influence toxicity. If the toxicity lines cross at or near 50 per cent mortality, then instead of basing upon the time required for 50 per cent kill, the slope of the line is used as a criterion for comparison, for under such conditions the slope apparently gives more information about the toxicity of the insecticide.

RESULTS OF TOXICITY STUDIES.—The results obtained are summarized in fig. 1

and table 2. In a given period after treatment, with each "inert" material, there was practically no difference in mortality between the series with food and without food. This is to be expected because the adult weevils have not been observed to feed on beans. With the exception of the test in which walnut shell flour was used, 100 per cent mortality was obtained in the insects became inactive about 24 hours after treatment. They lay on their backs and did not move unless touched with a dissecting needle. When dusted with amorphous silica and talc the insects were rather active and could climb up the wall of the glass container after 24 hours. Some insects treated with talc even laid eggs as usual.

Table 2.—Summarized data on toxicity of various materials to the bean weevil.

MATERIALS	CONDITION AFTER BEING DUSTED	DAYS REQUIRED TO KILL 50 PER CENT	DAYS REQUIRED TO KILL 100 PER CENT	SLOPE OF THE TOXICITY LINE
Crystalline Silica	No food	1.8	5.0	2.13
	With food	2.0	5.0	2.00
Amorphous Silica	No food	7.5	12.0	3.86
Magnesium Carbonate	No food	1.4	3.0	2.76
	With food	1.5	3.0	3.00
Bentonite	No food	<0.5	2.0	2.11
	With food	0.5	3.0	1.22
Talc	No food	7.4	17.0	1.20
Walnut Shell Flour	No food	13.5	22.0	—
Check	No food	12.5	15.0	—
	With food	14.0	23.0	—

2–17 days after treatment. The order of effectiveness was bentonite > magnesium carbonate > crystalline silica > amorphons silica > talc > walnut shell flour. It is interesting to note that the time required to produce 50 per cent mortality is the same for talc and amorphous silica, but the slope of the toxicity line for the latter is about three times greater than that for the former. This indicates that the time required to kill 50 per cent of the insects is sometimes an unsatisfactory basis for determining the relative practical values of insecticides.

Walnut shell flour showed no insecticidal value as used in these tests. Three days after being dusted, the treated insects were as active as the controls. They oviposited on the beans. Eight days after being dusted no insects were killed from the action of the material. This shows that this inert organic flour has some intrinsic properties quite different from those of the inorganic dust materials.

When dusted with bentonite, magnesium carbonate and crystalline silica

It was observed that all dusted insects tried hard to clean the dust off their bodies with their legs, mouth-parts and antennae. Upon examination under a binocular microscope, the mouth-parts and the surrounding region of the insect were seen to be full of dust.

RELATIVE TOXICITY OF DIFFERENT PARTICLE SIZES OF THE "INERT" MATERIAL.—In order to ascertain whether or not there is a definite correlation between the particle size of the "inert" material and toxicity, four samples of crystalline silica of different ranges of particle size were tested against the bean weevil. The particle sizes of three of these samples, fig. 2, were determined by the hydrometer method as proposed by Bouyoucos (1927a, b, 1928). The coarsest sample was measured by screen analysis, the numerical average of the screen openings between which they fell was taken as the mean diameter. The results of hydrometer analysis are expressed as percentages by weight of the material whose diameter is smaller than any indicated

value. They are plotted as a cumulative curve with the ordinate as percentage and the abscissa as the logarithm of the diameter of particles, fig. 2.

The average particle size of an "inert" materials are expressed with respect to surface. From the percentage of groups of average size particles obtained by hydrometer analysis, the average diameter in terms of surface of the dust material

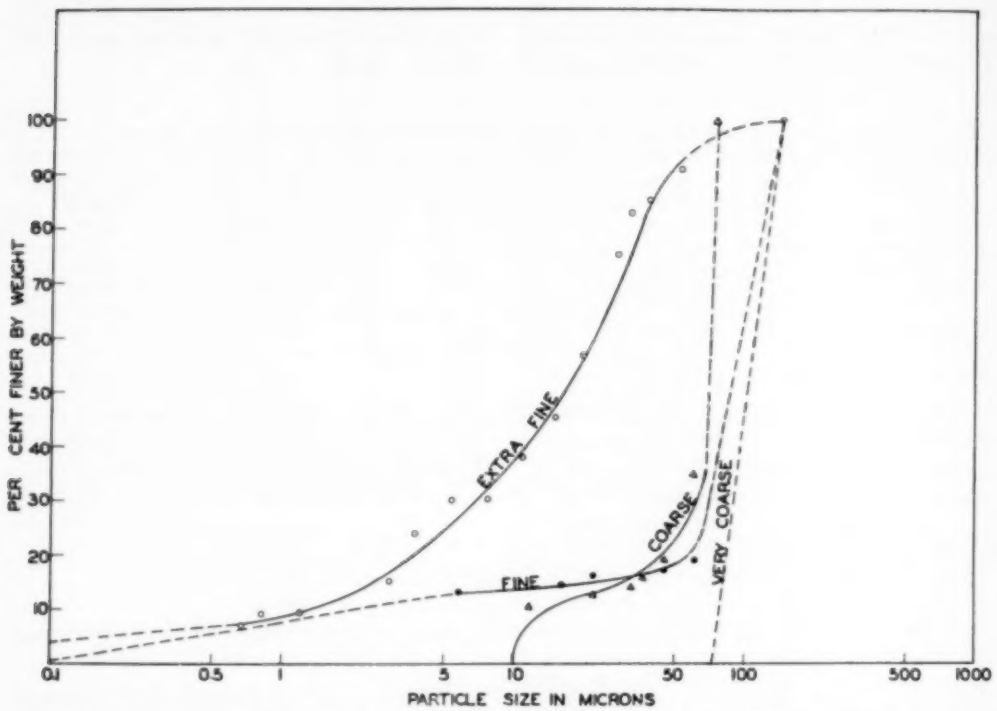

FIG. 2.—Cumulative frequency curves showing the relation of percentage by weight to diameter of particles of four samples of crystalline silica. The solid portion of each curve was based on the results of hydrometer analysis.

material should be expressed as a numerical value that has a definite meaning in relation to some physical property, such as surface and weight or volume. Here surface is the important consideration, for as will be pointed out later in this paper, the toxic effect of these "inert" materials probably lies in their surface activities. There is an enormous increase in surface per unit weight of a given substance with subdivision. The surface of a cube with the edge one centimeter long will be increased from 6 square centimeters to 6 square meters if it be divided into 1,000,000,000,000 cubes having the edge of one micron long. For spherical objects the specific surface, *i.e.*, the surface exposed by one gram of material, varies inversely with the average diameter of the particles. Therefore, in this investigation all the average diameters of the dust materials was calculated by the equation suggested by Weigel (1924):

$$d_{ave} = \frac{1}{\sum \frac{\text{per cent}}{\text{average diameter of fraction}}}$$

The average diameter in terms of surface may be interpreted physically as the diameter above and below which there are equal surfaces of material, and it corresponds approximately to the maximum of its surface distribution curve.

The results obtained in tests with different sized particles are given in table 3 and fig. 3. It is evident that the particle size is a very important factor influencing the toxicity of the material. The toxicity increases as the particle size of the material decreases. With particles over 100

microns in diameter, there is practically no toxic effect. It is the small portion of fine particles in the material, whose diameter is probably below 15 microns, that are responsible for the killing action. The great difference in toxicity due to different particle sizes can be explained on the basis of adhesion. In order to be effective the dust must firmly adhere to the insect body. Other things being equal, the adhesion of one substance upon another depends on the surface exposed and the weight of the particle adhered. Since the surface of the insect is fixed, the force of adhesion of the "inert" material to the insect body increases as the weight of the particle decreases and the surface of the particle increases. For a unit weight of a given material, the total surface is inversely proportional to the diameter of the particles, and the weight of each particle is directly proportional to its diameter. It can be shown that for a unit weight of a given material the adhesion between the surface of the particles and the insect body varies inversely as the diameter of the particles.

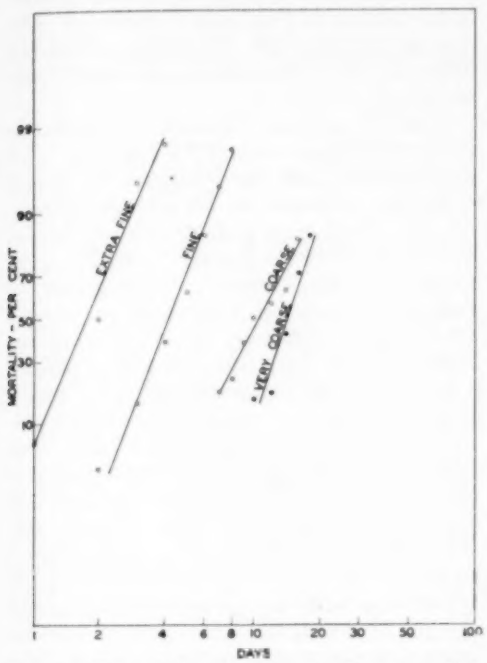

FIG. 3.—The relative toxicity of different particle sizes of crystalline silica to the bean weevil. (See table 3.) The mortalities on the line for the very coarse sample have not been corrected by Abbott's formula.

LOSS OF WEIGHT OF DUSTED INSECTS.—Since it has been theorized that the "inert" materials have desiccating action it was considered worth while to study the loss of water from the bodies of dusted insects. On the assumption that, with a living insect, a fraction of its weight loss is water, the loss of fresh weight is used as a measure of water loss. Thirty insects 1–3 days old were used in each series of the experiment. The insects were dusted with crystalline silica, magnesium carbonate, bentonite and walnut shell flour. After being dusted, they were transferred to a weighing bottle which was covered with a piece of muslin. They were kept without food in an environment of 27 degrees C. and 70–75 per cent relative humidity. Weighings were made at intervals of 24 hours until all the insects were dead and their weight became constant. An untreated lot of insects was run as a check.

The results, as represented in fig. 4, in-

Table 3.—Summarized data on the relative toxicity of different particle sizes of crystalline silica to the bean weevil.

Degree of Fineness	Diameter of the Particles, in Microns		Particles Below 10 Microns in Diameter (Per cent by weight)	Specific Surface,* Total Surface in m^2 Per Gm. of Material	Days Required to Kill	
	Range	Average (In terms of surface)			50 Per Cent	100 Per Cent
Extra fine	1–147	2.9	37	0.772	1.8	5.0
Fine	1–149	18.8	13	0.119	4.2	10.0
Coarse	10– 74	37.5	0	0.059	10.5	18.0
Very coarse	74–149	111.0	0	0.020	14.5	20.0
Check	—	—	—	—	14.0	>22.0

* Specific surface = $\frac{6}{\text{density} \times \text{average size}}$

dicate that there is a marked difference in the weight loss between the dusted and untreated insects. The curves for the rate of weight loss are similar in shape for the insects dusted with the effective "inert"

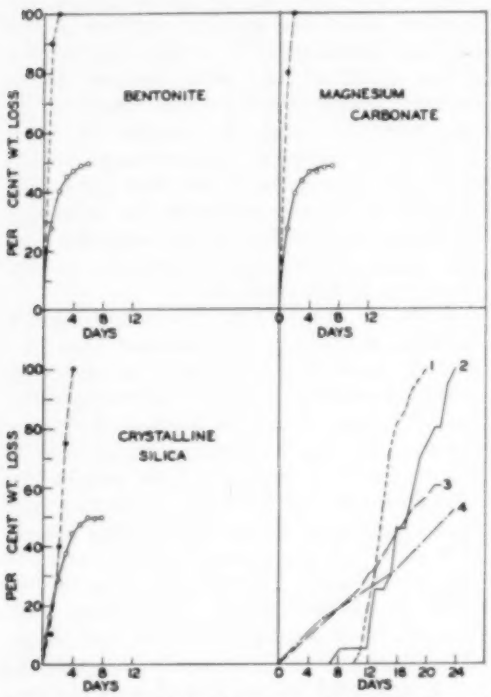

FIG. 4.—Effect of dusting upon the weight loss of the bean weevil. In the graphs for insects treated with bentonite, magnesium carbonate and crystalline silica, the percentages of weight loss of original fresh weight are shown by solid curves, the percentages of mortality of the insects by broken curves. Curve 1, percentages of mortality of insects treated with walnut shell flour; curve 2, percentages of mortality for untreated insects; curve 3, percentages of weight loss of original fresh weight for insects treated with walnut shell flour; curve 4, percentages of weight loss of original fresh weight for untreated insects.

materials. The weight loss was very rapid in the first two days; then it gradually declined, until finally it reached zero. The rate of weight loss of the dusted insects is greater with "inert" materials of higher efficiency than with those of low efficiency. With walnut shell flour, the weight loss of the dusted insects appears to be a linear function of time. In the first 10 days the curve for the weight loss practically coincides with the curve for the check.

It might be argued that the loss of water from the body of the dusted insect, as measured by the weight loss, is due to death rather than the effect of the dust. If we compare the results with those obtained for the untreated checks, it seems safe to conclude that, before the insect died, at least a fraction of the weight loss was water-loss which could be attributed to the action of the "inert" material. The dusted insects are, therefore, probably killed by the desiccating action of these materials.

EFFECT OF THE "INERT" MATERIALS UPON THE RESPIRATION OF INSECTS.—To ascertain whether the dust particles would plug the spiracles or in any other way interfere with respiration so that the insect would die of suffocation, studies were made on the oxygen consumption of dusted and normal insects. Bean weevils of 1–5 days old were used. Twenty insects dusted with the "inert" material were put in an experimental flask which was connected to a manometric respirometer. The flask was immersed in a water bath which maintained a temperature of 28.6 degrees C. The relative humidity in the experimental flask was 50 per cent. This was controlled by a small cup of aqueous potassium hydroxide solution which was hung on a glass bridge near the mouth of the flask. This solution likewise served to absorb the carbon dioxide given off by the insects. Observations were made on insects treated with crystalline silica and bentonite.

The results are summarized in table 4. The oxygen consumption of the insects is expressed as the volume (cubic centimeters) of oxygen required per hour by one gram of insect tissues. The data clearly indicate that there is no significant difference in oxygen consumption between treated and normal insects. Although some of the fine dust particles might penetrate into the tracheae, it is safe to conclude that these "inert" materials do not directly affect the respiration of insects.

The mode of action of the "inert" materials upon insects has been elucidated on four different bases: (1) ingestion of the dust into the digestive system (Richardson & Glover 1932; Boyce 1934; Samsonia 1936), (2) desiccating effect (Zacher & Kunike 1931; Hockenyos 1933; Germar 1936; Zacher 1937a, b), (3) chemical reaction with the body wall of the insect (Mackie 1930) and (4) direct mechanical

action (Germar 1936). The results of this investigation support the theory that the "inert" materials kill the insect by desiccation. For the bean weevil, the elimination of water through excretion is definitely restricted, the water loss is either through respiration or through evaporation from the surface of the body. Since it is found that the respiration of the dusted insect is normal, it is believed that the fine particles of the "inert" material, by means of their surface activities, draw water out from the insect body, which results in the death of the insect.

Table 4.—The effect of dusting upon the respiration of the bean weevil.

CRYSTALLINE SILICA*				BENTONITE			
Experiment	Time After Treatment in Hours	Oxygen Consumption, c.c. O_2 Per Gram Per Hour		Experiment	Time After Treatment in Hours	Oxygen Consumption, c.c. O_2 Per Gram Per Hour	
		Treated	Check			Treated	Check
No. 1	2	1.904	2.022	No. 1†	2	2.533	2.177
	4	1.730	1.743		3.5	2.098	2.042
	5	1.539	1.858		6	1.839	1.797
	7	1.778	1.535		8	1.724	1.782
	8	1.590	1.601		26	2.418	2.064
	10	1.539	1.415		27	2.298	1.638
No. 2	5	—	1.411	No. 2	2	2.384	2.174
	7	1.563	1.341		4	1.942	1.917
	9	1.417	1.236				
	11	1.431	1.211				
	26	1.739	1.434				
	29	1.789	1.392				

* In the first experiment one adult in the check dropped into KOH solution during the run. In both experiments, all insects were alive when the last reading was taken.
† 30% of the treated insects died after 25 hours.

Since it is found that the fine particles of the "inert" material, by means of their surface activities, draw water out from the insect body, which results in the death of the insect.

SUMMARY.—Laboratory experiments showed that certain so-called "inert" materials, when applied as dusts, are effective in killing adult bean weevils. Six different "inert" materials were tested. Bentonite was most effective against the insect, magnesium carbonate, crystalline silica, amorphous silica, talc and walnut shell flour were less effective in the order named. There was a definite correlation between toxicity and particle sizes of the "inert" materials, higher insecticidal efficiency being obtained with finer particles. It was found that insects dusted with effective "inert" materials lost weight very rapidly, which was assumed to be due mainly to the loss of water from the body. Respiration studies indicate that the "inert" material did not affect the oxygen consumption of the insect. It is thought that the "inert" materials killed the insects by desiccation.—11-18-38.

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Further Investigations With Japanese Beetle Repellents

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Investigations with tetramethylthiuram disulfide have been conducted continuously since the discovery of its repellency to Japanese beetle adults in 1935 (Guy 1936). On the basis of these promising results, limited quantities of this compound were released in 1937 to growers for trial. The results therefrom were, for the most part, highly encouraging; yet in certain localities protection of foliage was not entirely satisfactory. These instances of poor control were found to be due in large part to poor initial spray coverage and the lack of resistance of the spray residue to removal by rainfall. Laboratory, followed by field, experiments were, therefore, undertaken during 1938 in an attempt to correct these unfavorable physical properties.

LABORATORY TESTS.—Wetting and dispersing agents plus conditioners appear to be necessary for the satisfactory use of tetramethylthiuram disulfide in aqueous sprays applied with customary spray equipment. A mixture (coded 793 A4) containing 80 per cent of the thiuram disulfide, 18.8 per cent clay, 0.5 per cent *Lorol* alcohol and 0.7 per cent of a wetting agent* was developed for use during 1937. This mixture, unfortunately, produced a very stable suspension which gave poor initial coverage due to run-off and was not adhesive to foliage. Several formulae, in which the insecticidally inert ingredients were varied, were, therefore, tested on bean foliage to find a more adhesive and greater load-building spray mixture. In addition, several stickers were also investigated.

Bean test plants were uniformly sprayed with each composition by use of a turntable and paint spray gun. Several plants from each lot, after drying, were exposed to a spray of water falling from a constant head to simulate exposure to rain. Two leaves selected from each plant were washed with an organic solvent to remove the thiuram disulfide, and subsequently the area of each leaf was determined with a planimeter. Chemical analysis† of the solvent determined the load in micrograms per square inch of leaf surface. Tests against Japanese beetle adults, with smartweed plants treated in a similar manner, were also made to determine the effect of various stickers and dispersing agents upon the repellent action of tetramethylthiuram disulfide. All such laboratory tests with Japanese beetle adults were conducted by the method described by Fleming (1934).

On the basis of these studies the following mixture (793 A20) was found to be the most suitable for use on foliage: tetramethylthiuram disulfide 80 per cent, clay

* Cresol sulfonic acid-formaldehyde condensation product.

† Analyses performed by Dr. A. L. Flenner using an unpublished colorimetric method developed by Dr. N. E. Searle of the du Pont Experimental Station.

14 per cent, bentonite 5 per cent and *Lorol* alcohol 1 per cent. This composition disperses easily in water upon slight agitation, settles readily when not agitated and gives heavier initial spray deposits of greater adhesiveness to foliage than the 793 A4 composition used in 1937. The removal of the wetting agent increased the speed of settling of the solids in suspension, and the bentonite acted as a sticker. Although inert materials up to three times the weight of tetramethylthiuram disulfide were added to the mixture without affecting the control, increasing the percentage of bentonite from 5 per cent to 25 per cent in the above composition did not cause a further improvement in adhesiveness. Characteristic results obtained with the above mixtures, together with the effect of several stickers, are shown in table 1.

Table 1.—Effect of composition and added stickers upon spray deposits and foliage protection by thiuram disulfide.

Code No.	Added Stickers*	Initial Spray Coverage		Exposed to Artificial Rainfall	
		Micrograms Per Sq. In.	Per Cent Foliage Eaten	Micrograms Per Sq. In.	Per Cent Foliage Eaten
793 A4	(1937 composition) no sticker	169	34	117	65
793 A20	(1938 composition) no sticker	230	15	143	26
793 A20	Plus flour 1 lb.	207	22	153	31
793 A20	Plus flour 2½ lbs.	233	—	123	—
793 A20	Plus dried skimmed milk 1 lb.	174	12	83	26
793 A20	Plus rosin residue emulsion† 1 pt.	206	14	154	19
793 A20	Plus 1488 A8‡ 1 pt.	249	14	164	46
793 A12	Containing 25 per cent bentonite	—	17	—	28
793 A20	Plus zinc sulfate 1 lb. and hydrated lime 1 lb.	261	11	231	14
793 A20	Plus aluminum sulfate 1 lb. and hydrated lime 1 lb.	198	15	128	26

* All concentrations in pounds per 100 gallons. Tetramethylthiuram disulfide used at two pounds per 100 gallons regardless of the amount of inert ingredients.
† Rosin residue 50 per cent emulsion Goodhue-Fleming formula.
‡ 1488 A8, a rosin type experimental sticker.

It is evident from the results in this table that the spray load in micrograms per square inch was not directly correlated with protection of foliage. These results can be explained, however, when the type of coverage on the foliage is considered. It has been found that a light uniform film of the thiuram disulfide is much more effective in preventing feeding than a heavy, coarse, blotchy coverage. Tetramethylthiuram disulfide is definitely distasteful to the Japanese beetle and the prevention of feeding is apparently not due to its odor or color. A heavy, granular deposit as obtained with 1488 A8 was consequently less effective than the light, film-like load produced by the addition of dried skimmed milk.

Zinc sulfate plus hydrated lime was the most promising sticker tested. The zinc sulfate was added to the water first, allowed to dissolve, the lime was added and then the thiuram disulfide. It was later found that all three ingredients in this spray could be mixed together dry and added directly to the spray tanks with equally good results. When the quantity of the zinc sulfate and lime was reduced by one-half the initial control was as good, but the spray residue was apparently not quite so persistent. Increasing the proportion of lime from equal parts to amounts several times greater by weight than zinc sulfate caused a further loss in adhesiveness of the spray deposits. Zinc sulfate plus hydrated lime alone was no more effective than lime and aluminum sulfate in preventing feeding, and the plants so treated were entirely defoliated by the beetles in laboratory tests. Casein-lime, soybean flour and certain other proprietary stickers were also tested and found to be compatible with the thiuram

disulfide, but no more effective than those already mentioned. *Grasselli Spreader-Sticker*, on the other hand, when added to the repellent reduced the amount of foliage protection. Fish oil and petroleum oil emulsion could not be used since the tetramethylthiuram disulfide formed large gummy lumps in such combinations.

During these studies the compatibility of mixtures of the thiuram disulfide and several of the standard insecticides and fungicides was determined, table 2.

Table 2.—Compatibility of various insecticides and fungicides with tetramethylthiuram disulfide (793).

Code No.	Amount	Added Ingredients	Per Cent Foliage Eaten
793	2 lbs.	None	16
793	1 lb.	Plus derris (4% rotenone) 1 lb.	10
793	1 lb.	Plus lead arsenate 1 lb.	11
793	2 lbs.	Plus hydrated lime 5 lbs.	13
793	1 lb.	Plus phenothiazine 1 lb.	16
793	2 lbs.	Plus wettable sulfur 2 lbs.	14
793	2 lbs.	Plus Bordeaux (1–1–100)	30

With the exception of Bordeaux none of these materials reduced the efficiency of the repellent and none caused foliage injury. Although zinc or aluminum sulfates do not react, both copper sulfate and Bordeaux mixture do react with tetramethylthiuram disulfide at room temperatures regardless of the amount of lime included in the spray. The reaction products are definitely less effective in preventing feeding by the Japanese beetle than the parent material.

Field Experiments.—On the basis of the above laboratory investigations a series of experiments was undertaken to determine under field conditions the best compositions of tetramethylthiuram disulfide, together with the effect of several stickers upon such mixtures. Comparisons were also made of this compound, phenothiazine and derris.

Experiments on apple and peach trees were located in the same orchard as used in the last two years of studies (Guy & Schmitt 1937; Dietz & Pierpont 1938). This orchard is desirable for such tests because of its location in a heavily infested area and because of the number of both peach and apple varieties present. The orchard was divided into 15 blocks three rows wide and extending completely across it. With the exception of one combination, which was duplicated, each plot received a different treatment. Due to the unusually heavy rainfall of the past season, it was necessary to make three applications of all sprays on the following dates: July 5, 16, 26 and 27. The third application required two days because of mechanical difficulties with the equipment. All sprays were applied under 350–400 pounds pressure and at the rate of 4 gallons per tree. Timing of the spray applications was based on presence of beetles. The first spray was applied just as the insects had begun to infest the orchard in large numbers. The second spray was applied 11 days later after a delay due to rain and after considerable feeding had occurred in the poorest treatments. A period of heavy rainfall made the final application necessary since beetles had again begun to reinfest the orchard. The feeding injury was evaluated by the writers and two entomologists not connected with our organization. These two observers did not know the location of the various treatments. The amount of foliage consumed was placed in seven categories, namely: none, 0; trace, 0.5; very light, 1; light, 2; moderate, 3; heavy, 4; very heavy, 5. The sum of the products of such scoring was divided by the total number of trees to give the amount of feeding per plot. The averaged results of the four observations together with the efficiency ratings of the various treatments are given in table 3. The composition of the various spray materials was the same as that in the laboratory experiments.

When zinc or aluminum sulfates were used, they were added to the water in the spray tank first, allowed to dissolve, and the lime and finally the thiuram were added. In all other cases, the stickers were added last. Derris plus rosin residue emulsion (Plot 2) was included as the standard or reference treatment. Composition 793 A4 plus rosin residue emulsion (Plot 1) was included for comparison because it was the most effective combination in the 1937 experiments (Dietz & Pierpont 1938).

Although the various observers differed in their estimates of the amount of foliage eaten per tree, they were in agreement upon the relative efficiency of most of the

treatments. All selected the recommended mixture of derris at 4 pounds per 100 gallons plus 4 pounds of rosin residue emulsion as the least effective spray.

Experiments on ornamentals were located on a large estate approximately one mile east of the test orchard already described. A large number of a wide variety of ornamentals were sprayed with the mixtures listed in table 4.

Table 4.—Composition of sprays used on ornamentals.

Treatment	Concentration Per 100 Gallons
1. Cubé (4% rotenone)	4 lbs.
Rosin residue 50% emulsion	4 lbs.
2. Cubé	4 lbs.
1488 A8	1 qt.
3. Cubé	4 lbs.
Grasselli Spreader-Sticker	6 oz.
4. Cubé	4 lbs.
Dried skimmed milk	1 lb.
5. 793 A20	3¾ lbs.
Rosin residue 50% emulsion	1 qt.
6. 793 A20	3¾ lb.
1488 A8	1 qt.
7. 793 A20	3¾ lbs.
Zinc sulfate	1 lb.
Hydrated lime	1 lb.
8. 793 A20	3¾ lbs.
Aluminum sulfate	1 lb.
Hydrated lime	1 lb.

All spray deposits from the first application on June 24 were removed by extremely heavy rainfall on June 27 so that the sprays were re-applied on June 30. Additional rains made a third application necessary on July 7. This spray was followed by a long period of almost continuous rain, which seriously interfered with all field programs and made it impossible to spray these ornamentals again in time. Therefore, these experiments were discontinued.

Table 3.—Efficiency of various treatments upon apple and peach foliage.

Plot No.	Treatment and Concentration in Pounds Per 100 Gallons	Average Feeding Injury	Relative Efficiency
16	793 A20 5 lbs. (no sticker)	0.79	1
10	793 A20 2½ lbs. (no sticker)	0.88	2
11	793 A12 (50 per cent inerts) 4 lbs. (no sticker)	1.01	3
12	793 A20 2½ lbs. plus aluminum sulfate ¾ lb. and hydrated lime ¾ lb.	1.05	
15	793 A20 2½ lbs. plus zinc sulfate ¾ lb. and hydrated lime ¾ lb.	1.06	
5	793 A20 2½ lb. plus wheat flour 2 lbs.	1.12	4
8	76 A214† 3 lbs. plus 1488 A8 1 pt.	1.15	
1	793 A4 2½ lbs. plus rosin residue emulsion 1 pt.	1.15	
3 and 13	793 A20 2½ lbs. plus rosin residue emulsion 1 pt.	1.39*	5
7	76 A214 3 lbs. plus rosin residue emulsion 1 pt.	1.42	
6	793 A20 2½ lbs. plus dried skimmed milk 2 lbs.	1.45	
14	Derris‡ 4 lbs. plus *Grasselli Spreader-Sticker* 4 oz.	1.59	6
4	793 A20 2½ lbs. plus 1488 A8 1 pt.	1.65	
2	Derris‡ 4 lbs. plus rosin residue emulsion 4 lbs.	2.13	7

* Average of two plots, 3 (1.79) and 13 (1.00).
† Phenothiazine technical grade 92 per cent active 8 per cent conditioning agents.
‡ Airfloated ground derris root containing 5 per cent rotenone.

In this incompleted experiment, zinc sulfate plus lime plus 793 A20 was possibly the most effective and most persistent mixture applied. No significant differences, however, were noted among the various treatments because of the frequent rains occurring within one week of each application. Unfortunately, the mixture containing zinc caused foliage injury to *Prunus tomentosum* and *P. subhirtella*, two varieties of ornamental cherries, and a slight yellowing of the leaves of the silver lace vine, *Polygonum auberti*. However, other varieties of cherry and many other kinds of ornamentals were unaffected by this combination. The injury was due to the zinc salts since the tetramethylthiuram disulfide used alone had no adverse effect on any of the plants. The mixture of rosin residue emulsion and cubé foamed so badly that the spray tank agitator had to be stopped. The other cubé sprays also foamed, but to a lesser degree. When aluminum sulfate, lime and 793 A20 were mixed together before being added to the spray solution, a lumpy suspension was formed. The large lumps dropped to the bottom of the tank and plugged the drain. In contrast,

the zinc sulfate did not need to be previously dissolved in water to obtain a uniform spray suspension. A blotchy coverage on the foliage was obtained with the aluminum sulfate mixture and to a lesser degree with zinc sulfate. By an increase of the lime to twice the weight of the aluminum sulfate, a more uniform coverage was obtained. This mixture of 793 A20 5 pounds, hydrated lime 2 pounds and aluminum sulfate 1 pound, when applied on July 25, prevented all feeding until the end of the beetle season.

These field tests have confirmed our laboratory studies. The replacement of part of the clay with bentonite (793 A20) improved the protection of foliage due to the greater retention of the spray. Composition 793 A20 still needs an additional sticker under conditions of heavy rainfall. Increasing the amount of bentonite to 25 per cent (793 A12) did not further improve the insect control, although the fruit and foliage from this plot (10) had a visible spray residue at harvest. Composition 793 A20, without added stickers, was the best combination tested. The addition of rosin residue emulsion or 1488 A8 reduced the effectiveness of 793 A20, whereas rosin residue emulsion and 793 A4 was the most efficient combination tested in 1937 (Dietz & Pierpont 1938). Wheat flour and dried skimmed milk were of doubtful value as a supplement to this spray. Aluminum or zinc sulfates plus hydrated lime were promising supplements. The slight reduction in control with these stickers may have been due to uneven coverage, which can be corrected by increasing the quantity of lime. While better than derris, phenothiazine at 3 pounds was not equal to 2½ pounds of 793 A20. Sticker 1488 A8 improved the action of phenothiazine over rosin residue emulsion. Derris plus *Grasselli Spreader-Sticker* was better than derris plus rosin residue emulsion, the least effective treatment. On the basis of 1937 tests, all these treatments would have been more effective than lime and aluminum sulfate if this spray had been included.

SUMMARY.—A new composition of tetramethylthiuram disulfide, which greatly improved the retention of the active agent, has been found to be more effective in preventing feeding by the Japanese beetle than twice the concentration of derris or cubé. The outstanding treatment was 5 pounds of this new tetramethylthiuram disulfide composition which contained 20 per cent inert ingredients. Two and one-half pounds of this mixture was much more effective than 4 pounds of derris. With the possible exception of zinc or aluminum sulfates and lime, all other stickers investigated reduced the efficiency of this tetramethylthiuram disulfide composition. Tetramethylthiuram disulfide was found to react with copper and should not be used in combination with Bordeaux mixture, or before or after Bordeaux or other copper sprays. It can be safely mixed with lead arsenate, hydrated lime, wettable sulfur, phenothiazine or derris. Phenothiazine remains of interest and might have the added advantage of controlling codling moth in areas where this insect is a serious problem.—11-18-38.

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A NEW treatment for the Japanese beetle, which provides for fumigation with methyl bromide, has been approved by the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, as stated in Supplement 4 to circular BPQ—359, dated February 15, 1939.

Japanese Beetle Control Tests on American Elm Trees in Delaware

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The purpose of these tests was to determine the comparative efficiency of ground derris, tetramethyl thiuram disulfide, lead arsenate and hydrated lime, in combination with various adhesives as protectants for the foliage of American elm trees against the ravages of the Japanese beetle, *Popillia japonica* Newm. Fleming & Metzger (1936) proposed the use of 3 pounds of ground derris† having a 4 per cent rotenone content and 3 pounds of a 50 per cent rosin residue emulsion made according to the formula first suggested by Goodhue & Fleming (1936) as an effective spray for early ripening peaches and plums. Guy & Schmitt (1937), reporting experiments with certain thiuram sulfides, concluded that tetramethyl thiuram disulfide, 4 pounds, plus 1 pint of a 40 per cent rosin residue emulsion gave the best control of Japanese beetle in the case of several susceptible varieties of apples and peaches, but considered derris combined with rosin residue emulsion (50 per cent) almost its equal in efficiency. Dietz & Pierpont (1938) confirmed these results.

Protective sprays for shade trees, consisting of either lead arsenate, 6 pounds, with 4 pounds of wheat flour, or hydrated lime (20 pounds) with 3 pounds of aluminum sulfate, were recommended by Fleming & Metzger (1936).

These treatments are open to considerable objection. It was pointed out by Dietz & Pierpont (1938) that lead arsenate at the high and unbuffered concentrations at which it is thus used has the disadvantage of causing severe plant injury, and that hydrated lime has the conspicuous fault of building up unsightly deposits on ornamental plants and on fruit.

TEST BLOCK.—A planting of 25-year old American elm trees that had been severely attacked in previous years was selected for these tests. It is located on the University of Delaware campus at Newark, in the midst of an area of heavy infestation, and was exposed to attack from all sides during heavy migrations of the beetles.

SEASONAL INFLUENCES.—The period of beetle attack in 1938 was a very wet one. Hot days followed by rainy nights during the interval from June 30 to July 18 made control a very difficult problem. Adult emergence started during the last week in June, with a gradual increase in activity until about July 10. From July 10 to 19 the beetles were very abundant and feeding heavily. Frequent rains reduced the efficiency of the non-arsenical sprays and evidently aided in producing arsenical injury, which did not become apparent until later, however. Due to continued wet weather from July 19 until July 25, activity was at a minimum, the beetles clinging to unprotected plants and feeding all the while. A tremendous amount of arsenical injury appeared at this time. From July 26 to August 1 an extremely hot period occurred, and the beetles were again active and feeding heavily. A very hard rain fell during the early morning hours of August 2 that had a marked effect on the beetles. Very little activity, except on low growing plants, was noticed after this rain, and mortality greatly increased.

TEST METHOD.—The experiment consisted of the treatment of relatively large, unreplicated, exposed blocks of trees. Such procedure avoids the effect of the selection by the beetles of preferred trees on the performance of any treatment. Each of the test plots included eight trees.

The timing of sprays was based on frequent observations by the writer. The first application of the several treatments was made on July 1, immediately after migration into the area was observed. The second and third applications were made as soon as any heavy invasion of the treatments was noted; namely, July 7 and 16. A fourth application was made on July 27, immediately following the rainy period mentioned above.

The treatments tested are listed in table 1. All materials were applied at a

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† The composition of mixtures mentioned in this paper is based on 100 gallons of water.

gauge pressure of from 350 to 400 pounds. A single-nozzle, shade tree spray-gun was used, with particular care being taken to secure thorough coverage on both the lower and upper surfaces of the leaves. Each tree received approximately 25 gallons of spray and excessive run-off was avoided.

Table 1.—Composition of sprays tested for protecting the foliage of American elm trees against attack by the Japanese beetle.

TREATMENT	MATERIALS	COMPOSITION PER 100 GALLONS OF WATER
1	Hydrated lime	20 pounds
	Rosin residue emulsion	1 pint
2	Hydrated lime	20 pounds
	Aluminum sulfate	3 pounds
3	Tetramethyl thiuram disulfide	5 pounds*
	Rosin residue emulsion	1 pint†
4	Ground derris	4 pounds
	Rosin residue emulsion	4 pints
5	Ground derris	4 pounds
	Rosin residue emulsion	2 pints
6	Lead arsenate	6 pounds
	Wheat flour	4 pounds
7	Lead arsenate	2 pounds
	D-X	3 pints

* Tetramethyl thiuram disulfide refers to a compound containing 80 per cent active ingredients and 20 per cent inert ingredients.

† Rosin residue emulsion is the Goodhue-Fleming formulation.

A preliminary numerical rating of the plots was made on July 23. The following method, recorded by Dietz & Pierpont (1938), was used in evaluating results. The amount of beetle feeding injury was divided into five categories: none, 0; very light, 1; light, 2; moderate, 3; and heavy, 4. The number of trees in each category was multiplied by the number of the category and the sum of the products added together was then divided by the total number of trees. The figure thus obtained is considered the performance rating.

A final rating of the plots was made on August 6. Although no increase in damage was noticeable, an enormous amount of arsenical injury had developed and it was necessary to rate the efficiency of the combinations on this factor as well as on the degree of protection afforded the trees.

DISCUSSION OF RESULTS.—The data given in table 2 show that three treatments were very effective; *i.e.*, treatments 3, 4 and 5. These are, respectively, tetramethyl thiuram disulfide (5 pounds) and rosin residue emulsion (1 pint); ground derris (4 pounds) and rosin residue emulsion (4 pints); and ground derris (4 pounds) and rosin residue emulsion (2 pints).

Although these combinations did not afford the trees any better protection than the lead arsenate, they were more satisfactory in that no injury was incurred in using them. Lead arsenate (6 pounds) and 4 pounds of wheat flour, was responsible for a great amount of arsenical injury that resulted in a very heavy leaf drop. Lead arsenate (2 pounds) and *D-X* (3 pints) caused a severe curling and discoloration of the leaves.

The hydrated lime mixtures, although not as effective as the better treatments, were more efficient than lead arsenate, in that no injury resulted from their use.

CONCLUSIONS.—From these results it seems that either ground derris (4 pounds) or tetramethyl thiuram disulfide (5 pounds), combined with a suitable ad-

Table 2.—Results of spray treatments to protect the foliage of American elm trees against attack by the Japanese beetle.

TREATMENT	NUMBER OF TREES	NUMERICAL RATING	DEGREE OF PROTECTION	SPRAY INJURY	EFFICIENCY RATING
1	8	3.02	Fair	None	5
2	8	2.83	Fair	None	4
3	8	2.60	Good	None	3*
4	8	2.55	Good	None	2*
5	8	2.45	Good	None	1*
6	8	2.55	Good	Severe	7
7	8	1.86	Very good	Severe	6

* Best treatments.

hesive, such as rosin residue emulsion (Goodhue & Fleming), are at present the most effective protectants for the foliage of American elm trees against the ravages of the Japanese beetle. These combinations may be used without fear of injury to, or a building up of conspicuous residue on, such trees. An application should be made prior to any heavy invasion by this insect and the spray should be repeated as soon as any reinfestation is noted. —11-18-38.

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A Review of Cooperative Japanese Beetle Retardation Work in Maryland

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The Japanese beetle, *Popillia japonica* Newm., is a comparatively new insect pest in Maryland. In many parts of the state the beetle is not known to occur, but where it is abundant indications are that it will be one of the worst insects with which the Maryland people, both farm and city, have ever had to deal.

This pest feeds on over 200 different plants and it is known that under conditions of heavy infestation losses are large and control expensive. According to a report by the late L. H. Worthley of the U. S. Department of Agriculture, the average annual damage in heavily infested areas was determined to be as follows: field corn, 3½ to 80 per cent of the crop; sweet corn, 35 per cent of the crop; early apples, 43 per cent of the crop; early peaches, 27 per cent of the crop; general farms $1.76 per acre.

According to the same report it was estimated that annual expenditures for control in heavily infested areas were as follows for the items named: City blocks, $62.80 per block; sweet corn, $2.00 per acre; peaches, $8.00 per acre; apples, $7.15 per acre; estates, $513.00 per estate; golf courses, $618.00 per course and cemeteries, $225.00 per unit.

Because of these facts there has been a state-wide demand from Maryland people for the expansion of state and federal control activities.

JAPANESE BEETLE WORK IN MARYLAND PRIOR TO 1938.—The Japanese beetle first appeared in Maryland in 1926. As soon as the beetle was discovered, university officials, cooperating with the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, drew up a plan to suppress the insect where found and, at the same time give protection, through quarantine, to non-infested areas of the state. The plan met with favor among the farmers, nurserymen, shippers and fruit growers throughout the state, and, in 1937, to continue the work on a more adequate basis they obtained from the last legislature $40,000 of state funds in addition to funds allocated for quarantine purposes.

RETARDATION WORK, 1938.—It was felt that $40,000 was not sufficient to finance adequately a thorough-going Japanese beetle retardation program. Therefore, the state officials, cooperating with the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture inaugurated a broad Japanese beetle retardation program, stipulating

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that all work was to be done on a cooperative basis by the state, the federal government and the local people, with each of the cooperative units paying approximately one-third of the cost of the work. Appropriations and contributions for the work amounted to $95,899.16.

For operating purposes, the state was divided into three areas:

1. The uninfested areas
2. The lightly infested areas
3. The heavily infested areas

In the uninfested areas the quarantine work was continued, and educational work was done so that all of the people could know the things that they could do to aid the state in keeping beetles out of the free territory. The lightly infested areas involved those areas in Maryland which had one or more towns or localities infested with beetles. In these areas retardation work was done in an endeavor to keep the beetle from increasing in numbers and to delay the time when these minor infestations would develop into larger ones and radiate out into the surrounding country. The heavily infested areas consisted of territory in which the beetles were abundant and doing serious damage. In these areas large scale demonstrations were made to advise the people as to methods and means of controlling and retarding the development of the Japanese beetle.

In all of the infested areas, where practical, the following control activities were undertaken:

1. Trapping
2. Spraying
3. Soil Treatment
4. Colonization of parasites
5. Agricultural adjustment
6. Education

Along with the retardation activities, research work was done in an endeavor to improve present control methods and also to find more effective and practical control methods.

RESULTS OF PROGRAM.—Approximately 40,000 traps were operated in the state during the year. These traps caught 123,166 quarts or 615.85 barrels of beetles. Traps were operated in 89 cities, towns and villages. Demonstrational trapping was done in five heavily infested areas on farms in Cecil, Baltimore, Kent, Somerset and Worcester counties.

In an endeavor to determine the value of trapping under farm conditions and to determine whether or not Maryland farmers considered the use of traps practical, or worth while, an intensive cooperative trapping demonstration was undertaken in a selected area involving approximately 19 square miles in Cecil County. The plan called for the operation of one trap to each acre of open land in the area. However, due to failure on the part of the trap manufacturer to deliver an adequate supply of traps all of the farms in the area were not trapped. There were 77 farm properties in the area. Of this number of farms 58 used approximately 4,000 traps. Over 533 barrels of beetles were caught.

According to questionnaires sent out by the University of Maryland, 94.5 per cent of the farmers using traps favored the trapping idea, thought the traps were effective and want the program continued; 2.7 per cent opposed the work and 1.3 per cent were non-committal.

To be most effective, traps should catch enough beetles to make a noticeable reduction in Japanese beetle grub populations in the soil. An effort was made to determine the value of trapping in this regard, but results have not been consistent.

GRUB POPULATION IN THE TRAPPED AREA.—In the demonstrational area trapped in 1938 the grub populations in permanent pastures were found to be as follows:

1. Farms that operated traps had 35.1 per cent fewer grubs in October than in April, based on six square-foot samples per farm.

2. Farms that did not operate traps had 2.13 per cent more grubs in October than in April on the same basis.

3. The entire demonstrational area (both trapped and untrapped farms) had 24.68 per cent fewer grubs in October than in April.

GRUB POPULATION IN AREA UNTRAPPED IN 1938.—In an area, in which no traps were operated, about 80 square miles surrounding the trapping demonstration, three samples per square mile disclosed a general reduction in grub population. The April grub population in the untrapped areas was 11.78 per square foot in the 1937 infestation and 7.10 per square foot in the 1938 infestation.

The research work done in connection

with trapping consisted mainly in testing traps of different sizes and designs and in testing different materials for the improvement of baits.

The most significant accomplishment in trap research in 1938 is the assembly of a trap that can be manufactured complete, with standard or rod, for about 40 cents, as compared with $1.00 for the present trap.

SPRAYING.—Spray materials are effective in repelling the Japanese beetle. Spraying demonstrations were conducted throughout the state. The larger demonstrations were conducted in Elkton, Princess Anne, Pocomoke City, Baltimore, Beaver Dam, Kings Creek and Westover.

The spray work at Elkton was undertaken in cooperation with the city to demonstrate the value of spraying shade trees for protection from Japanese beetle damage. The work at the other localities was done for the purpose of finding out whether or not it was possible to reduce beetles around loading platforms. A reduction of beetles around loading platforms would be decidedly advantageous to shippers in handling produce under the quarantine regulations. Results showed that two applications of a spray of aluminum sulfate and lime reduced the beetle population in the vicinity of loading platforms 80 per cent below that of the surrounding unsprayed territory.

Tests on the efficacy of the protective value of the following spray materials were made on apple and shade trees. The sprays are listed in the order of their relative efficiency.

1. 2 pounds acid lead arsenate
   3 pints *D-X* (B. G. Pratt)
   Water, 100 gallons
2. 2 quarts McCormick's Japanese beetle spray
   Water, 50 gallons
3. 4 pounds acid lead arsenate
   2 pounds wheat flour
   Water, 100 gallons
4. 3 pounds tannic acid
   1 pint nicotine sulfate
   Water, 100 gallons
5. ½ pound colloidal lead arsenate
   Water, 100 gallons
6. 10 pounds derris (1 per cent rotenone)
   3 pounds rosin residue emulsion
   Water, 100 gallons
7. 4 pounds aluminum sulfate
   27 pounds hydrated lime
   Water, 135 gallons

The lead arsenate wheat-flour mixture was of value in protecting asparagus. Hydrated lime (25 pounds in 100 gallons of water) applied to soybeans, reduced the average number of beetles per plant from 128 on unsprayed plants to none on sprayed plants.

DUSTING.—About six acres of sweet corn were dusted with hydrated lime (55 pounds per acre) in the sweet corn section of Harford County to demonstrate the efficiency of dust in protecting sweet corn. Due to heavy rains at the time of dusting the results were not impressive. There is a feeling among some of the corn growers that dusting is not practical for them because beetles are not killed, but are only driven to other plants, including undusted corn fields. They claim their acreages are so large that it is impractical to dust all corn needing protection.

Hydrated lime dusted (scattered by hand—250 pounds per acre) over soy beans reduced the Japanese beetle infestation from an average of 90.5 beetles per square yard to 11.3 beetles per square yard. The disadvantage to this treatment is that following a rain the application must be repeated if protection is to be maintained.

SOIL TREATMENT.—Educational work on soil treatment was carried out in all of the counties of the state. Twenty-three actual demonstrations were made. As a result of these demonstrations many civic organizations and individuals are treating their lawns. Many communities are endeavoring to get all residents to treat their lawns. Soil treatment is effective in grub proofing for a period of five years. For the most part, soil treatment is applicable only to lawns, cemeteries, golf greens and private estates. It is felt that if all residents in cities and towns would treat their lawns their Japanese beetle problem would be reduced to a minimum. The treatment consists of applying 10 pounds of arsenate of lead to 1,000 square feet of lawn.

The research work on soil treatment consisted of comparing colloidal lead arsenate with standard lead arsenate. The colloidal lead arsenate was used at a dosage of 0.66 pound (manufacturers recommendation) and the standard arsenate of

lead at a dosage of 10 pounds (government recommendation) to 1,000 square feet of lawn. The applications were made in June, and results were checked in August and September. The average numbers of living grubs per square foot of soil at the time results were checked were as follows:

Colloidal lead arsenate	12.26 per square foot
Standard lead arsenate	1.26 per square foot
Check (untreated)	12.6 per square foot

COLONIZATION OF PARASITES.—Parasites are the natural enemies of the Japanese beetle and should afford an ideal way of combating them. With the cooperation of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, 300 colonies of *Tiphia vernalis* Roh. and 64 colonies of *T. popilliavora* Roh., a total of 364 colonies of parasites, were liberated in Maryland in 1938.

In order to get an even distribution of parasites in the heavily infested areas, geological survey maps of the areas were obtained and blocked off into square-mile areas. A colony site was located in each square mile, and a colony of parasites was liberated in each square mile insofar as parasites were available. The most favorable sites were used first.

AGRICULTURAL ADJUSTMENT.—There are crops that many farmers may not be able to grow economically under beetle conditions. It may be economical to replace them by some other crop that is not severely attacked. There are other crops in which planting dates should be changed, or possibly different varieties should be grown from those that are now being grown. Corn is an excellent example. If corn is planted so that it will silk after the first week in August, beetle damage can usually be avoided. To do this, in many localities it is going to be necessary to change the planting date; possibly change to new varieties. Observations for possible adjustments were made.

In cooperation with the Agronomy Department, tests were made in Cecil County with corn in 1938 to determine the most suitable varieties and the proper dates for planting under conditions of heavy Japanese beetle infestation. Ten varieties and two planting dates, May 13 and May 31, were used. The varieties were the following:

Lancaster Sure Crop, Golden Queen, Reid's Yellow Dent, Johnson County White, Eureka, National Hybrid 125, Hybrid (Indiana) 497-S, Indiana Hybrid 845, Funk Hybrid 235, Funk Hybrid 244.

Of the corn planted on May 13, no variety escaped excessive damage; 47.4 per cent (Eureka) to 78.5 per cent (Reid's Yellow Dent) of the ears showed damage, and the bushel loss per acre varied from 9.3 bushels (National Hybrid 125) to 23.9 bushels (Reid's Yellow Dent), but of that planted May 31, 4 out of the 10 varieties had less than 10 per cent damage and the bushel loss per acre varied from only 1.2 bushels to 14.7 bushels. The greatest damage suffered on any variety flowering after August 10 was 3.3 bushels per acre.

EDUCATIONAL WORK.—Educational work regarding the Japanese beetle and the fundamentals involved in its control was done in all sections of the state. Splendid cooperation was given in the educational work by extension people, 4-H Club boys and girls, vocational agricultural teachers, grade and high school teachers and students, the Farm Bureau, the Grange, garden clubs, women's clubs and civic organizations. The newspapers gave the work excellent support. Practically every newspaper in the state, both county and metropolitan, printed 1 to 10 or more stories on the Japanese beetle.

In initiating the educational work done by the above cooperators, the Department of Entomology of the University of Maryland contributed the following:

Lectures with exhibits	159
Demonstrations	118
Exhibits (fairs and shows)	15
Circulars distributed	80,000

PUBLIC RESPONSE.—The people in 22 counties were asked to support the cooperative program. The county commissioners in 21 of the counties cooperated. Aside from the cooperation on the part of the county commissioners, the officials in many cities and towns aided with the program.

Splendid cooperation in service, storage space or appropriations was given by many individuals, business houses and civic and business organizations.

PUBLIC OPINION.—All cooperating agencies, as well as the general public, are agreed as to the value of all phases of the work with the exception of trapping.

There is no unanimity of opinion as regards trapping, especially under farm conditions. In an endeavor to determine public reaction to trapping, a questionnaire was submitted to all individual farmers cooperating in the program and to a representative cross section of householders in heavily infested cities and towns. The following is a summary of the compiled information on three questions:

A. Do you like the Japanese Beetle trapping idea?
   Yes—94.7 per cent *No*—2.7 per cent
   Non-committal—2.8 per cent
B. Do you think traps are effective in catching beetles?
   Yes—92.7 per cent *No*—3.6 per cent
   Non-committal—3.6 per cent
C. Were you satisfied with the program and do you think it should be continued?
   Yes—95.1 per cent *No*—2.4 per cent
   Non-committal—2.4 per cent

—11-18-38.

The Tarnished Plant Bug as an Apple Pest*

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A curious type of dimpled injury has been noted on apple fruits in eastern New York fruit districts during the past few years. Usually less than 1 per cent of the fruit in any one orchard has been so affected, but the injury has been found throughout the entire area. In appearance, it more or less resembled the injuries produced by the apple redbug, *Lygidea mendax* Reut.; the apple curculio, *Tachypterellus quadrigibbus* (Say); the apple seed chalcid, *Callimome druparum* (Boh.); and certain other insects; but the blemishes were not typical of those caused by any of these species. The amount of this injury became greater in 1936 and 1937 and was so abundant in several orchards that growers became alarmed.

A search of the literature for some clue as to the cause of this trouble revealed that the tarnished plant bug, *Lygus pratensis* (L.), was the most likely suspect. Taylor, in 1908, described and illustrated tarnished plant bug injury on apples which appeared identical with the type of injury under discussion and studies in 1938 revealed that the tarnished plant bug was indeed the cause of this trouble. There are numerous references in the literature to tarnished plant bug injury to apple, pear and other fruit trees, but in most instances the injury described is a blasting of blossoms or buds. Observations in the Hudson Valley area indicate that very little blasting of apple buds occurs and that so far the injury to the fruit has been of far greater importance.

An orchard consisting mainly of Duchess and Williams Red apple trees, and which showed considerable injury to the 1936 and 1937 crops, was selected for the 1938 studies reported here. Examinations of the planting were made periodically, starting early in the season as the apple buds began to open and continuing until the insects became scarce in the trees. Overwintered adults began feeding on apple buds soon after the delayed-dormant bud stage and were most abundant during the pink and blossom period. Oviposition in the blossom buds began as soon as the stems started to separate in the clusters and egg laying in the fruit was continued until the apples were about one-half inch in diameter, figs. 1 and 2. The insects then became scarce in the trees, having migrated to weeds and various other herbaceous plants in the near vicinity. Of the several species of weeds growing in and near the orchard the common wild mustard, *Brassica nigra* (L.) Koch., was the preferred host.

Affected fruit may exhibit both feeding and oviposition injuries. These are illustrated on the same apple in fig. 3. As may be seen, the feeding puncture usually shows a small and superficial type of injury, whereas the oviposition puncture causes a deep depression and distortion of the fruit. Most of the injuries are inflicted in the calyx tube near the base of the sepals and petals and therefore the blemishes on the mature fruit appear at the calyx end. However, some injuries, and

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† The writer wishes to express his thanks to R. W. Dean for the use of his unpublished photograph of the adult apple redbug.

FIG. 1.—Left, six eggs in position and, right, caps of three eggs deposited by *Lygus pratensis* in the calyx tube of apple

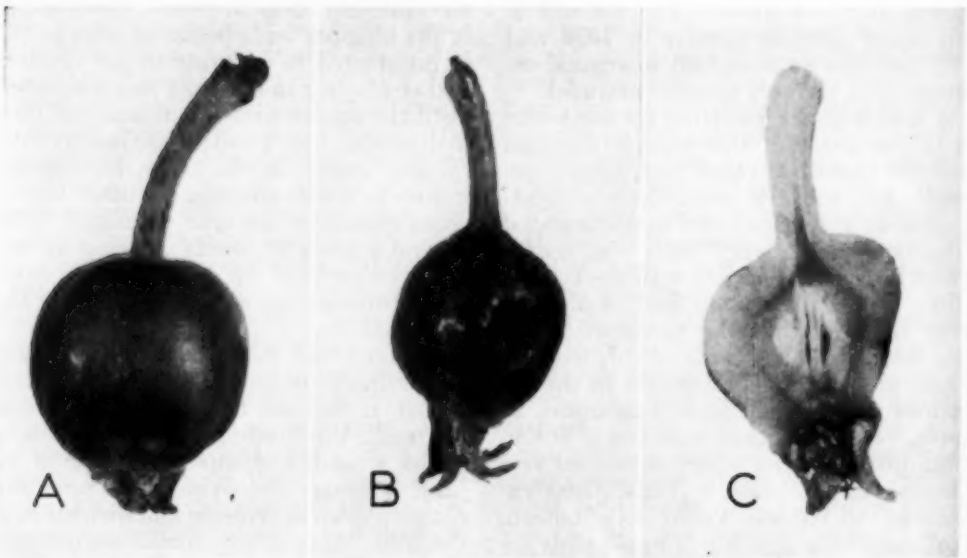

FIG. 2.—*A* and *B* show dimples in Duchess apples approximately 15 days after petal fall. *C* shows section through Duchess apple in early stage of deformation of fruit caused by an oviposition puncture of *Lygus pratensis*.

particularly those made after bloom, may be found elsewhere on the fruit surface. According to Taylor (1908) some of the eggs deposited in the apples hatch; the incubation period in Missouri is eight days.

Apple varieties react differently to tarnished plant bug oviposition wounds. In the fruit of such varieties as Delicious, Cortland and Ben Davis very deep depressions usually result, while in Duchess, Greening and Baldwin the depressions are less pronounced. Injury produced by this insect seldom renders the fruit unmarketable, although the blemishes may relegate it to inferior grades.

Newcomer (1933), referring to the injury caused by the feeding of this bug in the Pacific Northwest, states, "The degree of injury is contingent not only on the number of bugs, but on weather conditions. Continued periods of settled warm weather in March and early April, coming before alfalfa and other ground crops have developed, cause the bugs to feed in the trees; cold, rainy or windy weather at this time prevents extensive feeding." It has been the observation of many investigators that tree crops under early season cultivation, and situated near hedge rows, ditch banks and other suitable hibernation quarters are more seriously injured than those grown under opposite conditions. The writer, however, has observed tarnished plant bug injury in orchards maintained in sod; in fact, the most severe infestation noted during 1938 was in an orchard that had not been cultivated for several years.

CONTROL STUDIES.—A preliminary control test was conducted in 1938. The data obtained, while inconclusive, appear sufficiently interesting to be presented here. Some of the materials used were those reported by Hill (1933) as being effective against this pest on celery.

These tests were conducted in a planting containing mostly Duchess and Williams Red apple trees. There were a few trees of other varieties in the planting which were treated along with the two named. The planting was divided so that there were approximately 50 trees in each of the five test plats, and each plat contained an equal number of trees of each of the varieties represented. An attempt was made to arrange the plats so that when the treatments were made there would be a minimum drift of spray or dust from one plat to another. The spray and dust mixtures were applied with modern commercial equipment; all the plats being treated on the same day. Only two applications were directed specifically against the tarnished plant bug. The first of these was made on April 29, at which time Duchess were in full bloom and Williams Red blossoms were just beginning to open. The second treatment was made on May 6 when about 95 per cent of the petals were off the Duchess and about 60 per cent were off the Williams Red.

FIG. 3.—Apple showing five feeding scars and one oviposition scar resulting from several eggs of *Lygus pratensis* deposited in close proximity.

The data on protection afforded by the various materials tested were obtained by an examination of all the thinned, dropped and picked fruits from each of three trees similarly located in each plat. The results obtained and the materials used in each plat are presented in the accompanying table.

On the basis of studies of the activities of the tarnished plant bug and the control results obtained in 1938, it now seems that the treatments were applied a few days too late to secure maximum protection from this pest. While the data presented in table 1 are inconclusive, it appears that in order to reduce tarnished plant bug injury to apples the first treatment should be applied as soon as the bugs become numerous in the trees, and further treatments should follow at short

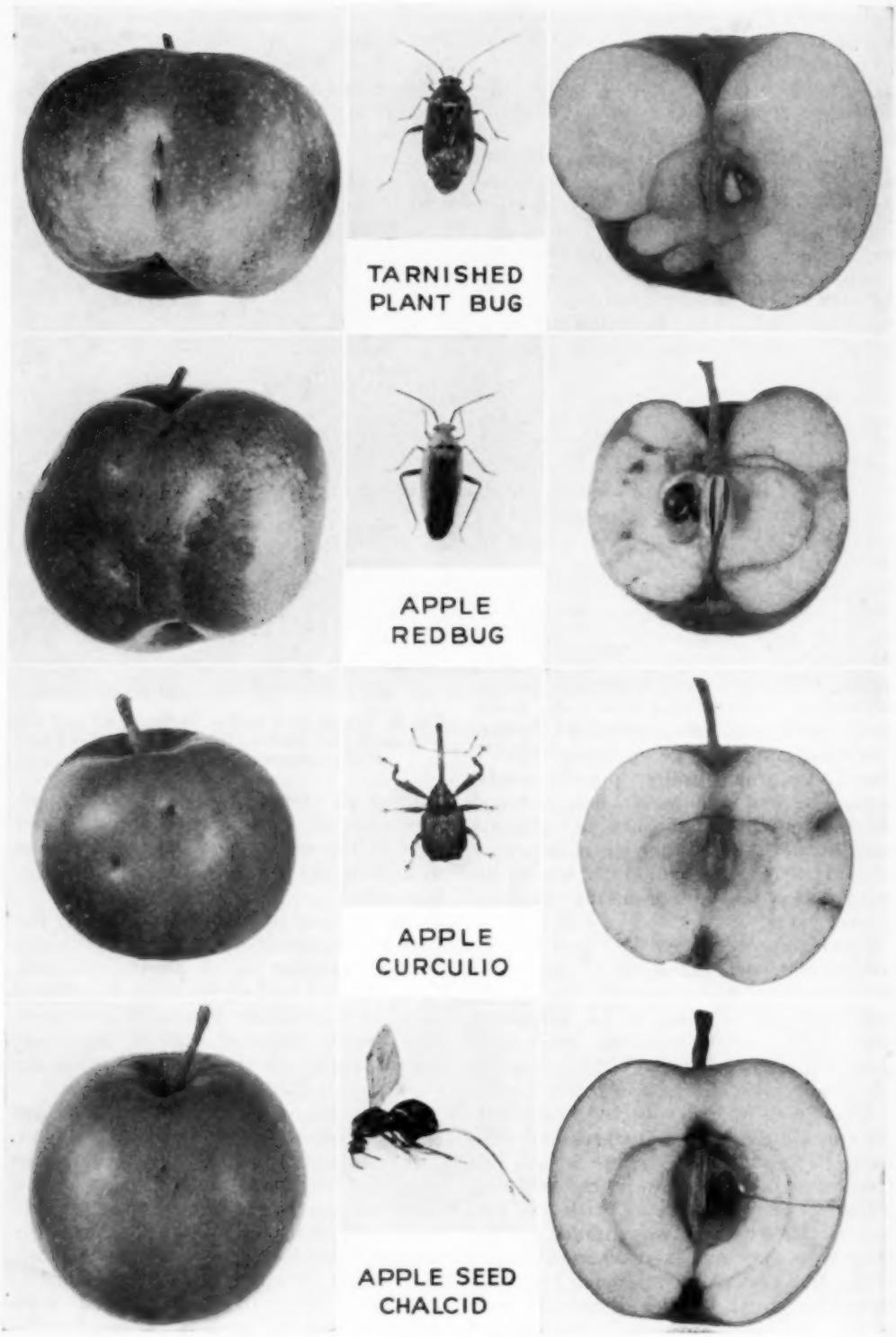

FIG. 4.—External and internal injuries of apples and the insects causing them.

intervals (five to seven days), until most of the bugs have migrated to other plants.

TARNISHED PLANT BUG INJURIES COMPARED WITH INJURIES BY OTHER INSECTS.—As was mentioned earlier, injury to apples caused by the tarnished plant bug is often confused with somewhat similar injuries caused by the apple redbug, the apple curculio and the apple seed chalcid. As an aid in differentiating the blemishes caused by these four insect species, photographs of their injuries, both external and internal, are shown in fig. 4.

The feeding punctures of the tarnished plant bug usually result in small surface scars with very slight depressions, or none at all, surrounding the scars. Externally the egg punctures usually result in conspicuous depressions. The margins of the depressions are elliptical or subelliptical in outline, and typically very little or no russeting occurs. Longitudinal sections through the depressions show them to extend either to the core of the fruit or to the fibrovascular bundles, which appear to be pulled outward at the point of injury.

Apple redbug fruit injury results from feeding activities. Usually the punctures take the form of shallow pits surrounded by russeted areas. When the punctures are numerous the fruit surface becomes roughened and gnarly. Sections through apples injured by the apple redbug often show corky brownish areas directly beneath the pits. The fibrovascular bundles are often injured and indicate this by irregularities in their course through the flesh of the fruit.

In many ways the feeding and oviposition punctures of the apple curculio closely resemble those of the tarnished plant bug. However, the margins of the depressions caused by the apple curculio are more nearly circular in outline. The oviposition punctures of the apple curculio are always closed by a pellet of excreta which usually remains in position throughout the life of the fruit. In section, the punctures and underlying cavities formed by the apple curculio show as darkened lines which extend a short distance beneath the surface and then widen out into cavities of various sizes.

Injuries to apples caused by the apple seed chalcid result only from oviposition. In some instances very shallow depressions develop around the points of injury, but many are barely visible to the naked eye. Where many punctures are made in a single fruit the apple may become slightly misshapen. While the degree of deformity depends upon the intensity of the attack and the variety of fruit affected, it rarely is deformed to the same extent as apples injured by the other three insect species mentioned. Internally the injury of the apple seed chalcid con-

Table 1.—Results of 1938 control experiments against tarnished plant bug injury to apple fruits.

Plot No.	Method	Spray or Dust Formula*		Variety	Number Apples Examined	Number Injuries Per Injured Fruit	Per Cent Fruit Injured
		April 29 Application	May 6 Application				
1	Spray	Sulfur 6 lbs. Soybean flour 1 lb. Hydrated lime 1 lb. Nicotine sulfate 1 ½pts.	Same except lead arsenate 3 lbs. included	Williams Red Duchess Duchess	1,499 3,733 5,114	1.45 1.83 1.84	15.68 15.88 17.78
2	Spray	Sulfur 50 lbs. Hydrated lime 50 lbs. Soybean flour 1 lb.	Same except lead arsenate 3 lbs. included	Williams Red Duchess Duchess	1,294 5,812 6,069	1.35 1.65 1.75	9.58 8.18 8.98
3	Dust	Sulfur 50 lbs. Hydrated lime 50 lbs.	Sulfur 45 lbs. Hydrated lime 45 lbs. Lead arsenate 10 lbs.	Williams Red Duchess Duchess	1,470 2,887 3,711	1.38 1.77 1.99	12.65 14.92 14.06
4	Dust	Sulfur 90 lbs. †*Dry Pyrocide* 10 lbs.	Sulfur 50 lbs. †*Dry Pyrocide* 10 lbs. Inert clay 30 lbs. Lead arsenate 10 lbs.	Williams Red Duchess Duchess	2,895 4,945 5,175	1.48 1.50 1.78	9.56 7.48 7.69
5	—	No treatment for tarnished plant bug (check plat)	Same as for April 29	Williams Red Duchess Duchess	2,377 3,383 4,456	1.47 1.87 1.72	16.07 19.33 16.22

* Where sprays are indicated the amounts given represent the amounts used per 100 gallons. The dust formulae given are for 100 pounds of dust. The sulfur used was a sublimed elemental sulfur of 325 mesh. The nicotine sulfate contained 40 per cent nicotine.
† *Dry Pyrocide* is a proprietary pyrethrum product obtained from McLaughlin Gormley King Co., Minneapolis, Minn. The *Pyrocide* dust mixture used on April 29 has very poor dusting properties, although that used on May 6, was very satisfactory.

sists of a very slender brown line extending from the surface of the fruit directly toward the seed. Occasionally the lines do not reach the core and these represent unsuccessful attempts at oviposition.

Obviously there are many variations in the appearance of the injuries caused by these four insect species. In almost all instances, however, the cause of the injuries may be identified either on the basis of external or internal characteristics, or both.—11-17-38.

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Dinitro-O-Cresol, Dinitro-O-Cyclo-Hexylphenol and Lauryl Rhodanate in Dormant Sprays Against Eggs of Apple Aphids

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The advantage of a complete dormant spray for cleaning up scale insects and aphids on fruit trees has been recognized for many years. Delay in developing such a spray was largely due to the difficulty of finding an effective ovicide for aphid eggs. Introduction of coal-tar distillates for this purpose offered the first practical solution of the problem, but experience of the past eight seasons in a section of the country where coal-tar distillates are widely used convinces us of the need for an ovicide which is less objectionable to the men who do the spraying. Caustic action of the tar distillate on the human skin is particularly severe and painful when the temperature is moderately high.

Ovicidal action of certain benzene derivatives was first investigated by Tattersfield, Gimingham, *et al.* (1925, 1926), who found that 3:5-dinitro-o-cresol and its sodium salt killed the eggs of some insects including the eggs of an aphid, *Phorodon humuli* (Schr.). On the strength of these reports we included both compounds in 1927 in our experiments with ovicides for aphid eggs on apple trees. According to recent laboratory tests by Kagy & Richardson (1936), dinitro-o-cyclo-hexylphenol in oil is an effective ovicide for several species of insects; and Dutton (1936) used this compound in oil in dormant applications for control of San José scale and rosy apple aphid. This compound has been included in our orchard experiments of the past three seasons. Experimental data presented by Kearns & Martin (1935) indicated high ovicidal efficiency of lauryl rhodanate against the eggs of *Aphis pomi* DeG. Our orchard experiments with this material began in 1937.

The purpose of this paper is to report the results of some of our tests with the various materials mentioned. All of the materials have been used in dormant sprays in rather extensive orchard experiments through two or more seasons. The scope of this paper, however, is limited to certain tests (mostly on single trees) designed especially to ascertain the efficiency of the toxic materials in killing aphid eggs. Petroleum oil was used in many of the tests because in practical operations it is usually necessary to include oil as a scalecide.

PROCEDURE.—Apple trees on which a large number of aphid eggs could be found were selected for spraying. The trees were mostly 3 to 10 years of age. A hand spayer was usually employed in making the applications on the small trees, and one preparation was applied to a single tree. A power sprayer was used in spraying the larger trees, in which case several trees received the same preparation. After hatching was completed in April or early

* The writer is indebted to Erma Groves for assistance in examining the eggs during the spring of 1938.

May, small branches were cut and brought to the laboratory where the eggs were examined under a binocular microscope. In 1938, however, the procedure was changed slightly. The branches or twigs were cut and brought to the laboratory in March just before hatching was expected. The branches were cut into sections and the number of eggs counted on each section, after which the section was placed in a glass tube 12 inches long and three-fourths inch in diameter. Each end of the tube was plugged with cotton. The tubes were kept in a screened insectary, exposed to outdoor temperatures but not to direct sunlight. When hatching was completed the contents of the tube was placed on white paper under a microscope and examined for aphids. The cotton plugs and glass tube were likewise examined for aphids that might have adhered to them. This procedure eliminated the difficulty of trying to determine a "hatched egg" from an egg which had lost its dead embryo through a split in the shell.

COAL-TAR DISTILLATE.—Although sprays containing a combination of tar distillate and petroleum oil have been widely used in Virginia orchards for seven seasons, the results of some tests are given in table 2 (nos. 5, 6, 13, 14, 21, 22, 53 and 58) as a standard for comparing the results obtained with the other materials. Experience has shown that not less than 2½ per cent tar distillate is required in fall applications for adequate control of apple aphids, but 2 per cent tar distillate may give satisfactory control when applied in March. On the basis of this experience it is fair to assume that equivalent control should be obtained with other ovicides, if they are to be considered effective. In other words, an effective ovicide should give not less than 95 per cent control.

A number of tests were made with a material prepared by drying coal tar. It is sufficient to record the results of two tests (nos. 19 and 20) to show that this material was practically without value as an ovicide.

EFFECT OF EMULSIFIERS.—Various mixtures of bentonite and dried sulfite waste, or lignin pitch (*Goulac*), were used in emulsifying most of the oils in the tests of the past two seasons. The proportions used in each test are shown in table 3. Effect of the emulsifier in some of the tests was important, for example, when the concentration of *Goulac* in the diluted spray amounted to 10 or more ounces per 100 gallons, the run-off was excessive with a consequent reduction in control as in nos. 7, 8, 12, 13, 14, 15, 16, 17 and 18 of table 2.

DINITRO-O-CRESOL.—In March, 1927, a number of tests (involving 4,123 eggs) were made with 3:5-dinitro-o-cresol in which either a soluble cresol dip or high-flash naphtha was used as the solvent. Neither of the solvents was very effective as an ovicide when used alone. Eight concentrations of dinitro-o-cresol were used ranging from 0.83 pound to 8.34 pounds per 100 gallons. All eggs were killed when sprayed with concentrations of 2.5 pounds and above per 100 gallons. At 2.07 pounds, 90 per cent control was obtained when the dinitro-o-cresol was used alone, but in the single test in which it was combined with 3 per cent petroleum oil all of the 345 eggs were killed.

All other tests with dinitro-o-cresol mentioned in this paper refer to the use of its sodium salt (sodium dinitro-o-cresylate), but dosages are calculated as dinitro-o-cresol. The tests were begun in January, 1927, and were concluded in 1929, and involved orchard experiments in addition to the tests on single trees on which the aphid eggs were examined.

Sodium dinitro-o-cresylate was prepared by adding dinitro-o-cresol to a solution of sodium carbonate and stirring until dissolved. In most instances stock material was prepared by dissolving 50 grams of sodium carbonate in 1,000 cubic centimeters of water and then gradually stirring in 50 grams of dinitro-o-cresol. An orange precipitate formed which dissolved on further dilution with water.

Sodium dinitro-o-cresylate was used alone and in combination with petroleum oil. Except in the three tests where miscible oils were used, all of the petroleum oil emulsions were cold-mix soap-cresol emulsions in which *Junior Red* engine oil was employed. The results of the tests for each of the four seasons are combined and summarized in table 1. Wherever the same materials were used in two or more tests, average per cent hatched and control are indicated for all of the tests made. The per cent control is calculated according to the formula of Abbott (1925) and

is based on the average hatch of the unsprayed eggs for the four seasons.

It will be observed that the higher concentrations of sodium dinitro-o-cresylate (dinitro-o-cresol at 2.5 and 2.9 pounds per 100 gallons) gave a high degree of control when used alone. It is also evident that the use of oil with sodium dinitro-o-cresylate increased the efficiency of the spray. Oil improved the wetting capacity of the spray solution and also killed many eggs when applied at the time the eggshells were split. Sodium dinitro-o-cresylate was no more effective when used alone just prior to the hatching of the eggs than in earlier applications.

ing tank-mix oil emulsion and (3) a wettable powder. Various mixtures of bentonite and dried sulfite waste or lignin pitch (*Goulac*), as shown in table 3, were used in emulsifying the oil containing dinitro-o-cyclo-hexylphenol. In a few tests the dry-mix compound was also used as a wettable mixture without the addition of petroleum oil. The approximate amount of dinitro-o-cyclo-hexylphenol in the diluted spray mixture is shown in table 2.

Table 1.—Results of experiments with dinitro-o-cresol in dormant sprays in which it was converted to sodium dinitro-o-cresylate.

Date	Materials and Amount Per 100 Gallons	Number of Eggs Examined	Per Cent Hatched	Average Per Cent Hatched	Average Per Cent Control
Jan. 31, March 14, 1927	Dinitro-o-cresol 2.9 lbs.	786	0.38	1.69	98.1
Feb. 23, March 16, 1928	Dinitro-o-cresol 2.9 lbs.	100	3.0		
Feb. 13, Feb. 15, 1929	Dinitro-o-cresol 2.9 lbs.	1,318	2.1		
Feb. 23, March 4, 1930	Dinitro-o-cresol 2.9 lbs.	953	1.3		
March 1, 1927	Oil 3% and dinitro-o-cresol 2.9 lbs.	423	0.0	0.0	100.0
March 14, 1927	Oil 3% and dinitro-o-cresol 2.9 lbs.	335	0.0		
Jan. 31, March 14, 1927	Dinitro-o-cresol 2.5 lbs.	420	0.0	3.2	96.5
Feb. 23, March 16, 1928	Dinitro-o-cresol 2.5 lbs.	102	7.8		
Feb. 13, Feb. 15, 1929	Dinitro-o-cresol 2.5 lbs.	876	2.3		
Feb. 23, 1930	Dinitro-o-cresol 2.5 lbs.	585	2.7		
March 1, 1927	Oil 3% and dinitro-o-cresol 2.5 lbs.	439	0.0		100.0
Jan. 31, March 14, 1927	Dinitro-o-cresol 1.6 lbs.	345	1.1	7.1	92.2
Feb. 23, March 16, 1928	Dinitro-o-cresol 1.6 lbs.	103	8.7		
Feb. 13, 1929	Dinitro-o-cresol 1.6 lbs.	477	12.3		
Feb. 23, 1930	Dinitro-o-cresol 1.6 lbs	458	6.1		
March 1, 1927	Oil 3% and dinitro-o-cresol 1.6 lbs.	283	0.0		100.0
Feb. 23, 1928	Miscible oil 5 gal. and dinitro-o-cresol 1.6 lbs.	55	3.6		96.0
March 16, 1928	Miscible oil 5 gal. and dinitro-o-cresol 1.6 lbs.	38	10.5		88.5
Jan. 31, March 14, 1927	Dinitro-o-cresol 0.83 lb.	626	9.1	33.2	63.8
Feb. 23, March 16, 1928	Dinitro-o-cresol 0.83 lb.	116	19.8		
Feb. 13, 1929	Dinitro-o-cresol 0.83 lb.	485	70.9		
March 1, 1927	Oil 3% and dinitro-o-cresol 0.83 lb.	342	4.6		94.9
March 1, 1927	Oil 3%	426	88.2	43.6	52.5
March 14, 1927*	Oil 3%	366	15.3		
Feb. 23, 1928	Miscible oil 5 gal.	57	36.8		59.9
1927	Check, not sprayed	1,650	93.8	91.8	
1928	Check, not sprayed	138	86.9		
1929	Check, not sprayed	349	95.1		
1930	Check, not sprayed	466	91.4		

* When aphid eggs were split and ready to hatch.

DINITRO-O-CYCLO-HEXYLPHENOL.—Data on tests made for the purpose of examining aphid eggs sprayed with dinitro-o-cyclo-hexylphenol are limited to the past two seasons as shown in table 2. The toxic material was used in three preparations as follows: (1) dissolved in petroleum oil, (2) a dry-mix consisting of the toxic material and emulsifier for preparIt will be observed that dinitro-o-cyclo-hexylphenol at about 9.5 to 9.8 ounces per 100 gallons used alone (nos. 33, 34 and 60) or in petroleum oil (nos. 3, 24, 39 and 59) gave better than 95 per cent control, except in no. 8 where the emulsifier caused excessive run-off and in no. 54 where the application was made on December 2 under adverse (cold and windy) weather conditions. A dry-mix emulsifier containing the toxic material was used to prepare tank-mix oil emulsions in a few tests, and according to the results (nos. 9, 10, 11 and 12) the control appeared com-

Table 2.—Dinitro-o-cyclo-hexylphenol (DNOCHP) and lauryl rhodanate compared with coal-tar distillate as an ovicide against the eggs of apple aphids.

No.	Date	Materials and Amount Per 100 Gallons	Number of Eggs Examined	Per Cent Hatched	Per Cent Control
	1936	*J. D. Marker's Orchard*			
1	Nov. 25	Oil 1% (DNOCHP 4.9 oz.)	250	11.6	84.0
2	Nov. 25	Oil 1½% (DNOCHP 7.4 oz.)	550	7.4	89.7
3	Nov. 25	Oil 2% (DNOCHP 9.8 oz.)	187	3.2	95.5
4	Nov. 25	Oil 2½% (DNOCHP 11.02 oz.)	1,762	2.2	96.9
5	Nov. 25	Oil 2½% and tar distillate 2%	956	6.9	90.5
6	Nov. 25	Oil 3% and tar distillate 2½%	601	1.1	98.4
	1937				
7	Feb. 12	Oil 1% (DNOCHP 4.9 oz.)	765	43.1	40.7
8	Feb. 12	Oil 2% (DNOCHP 9.8 oz.)	129	17.8	75.4
9	Feb. 12	Oil 1% and dry-mix .88 lb. (DNOCHP 4.9 oz.)	1,348	20.1	72.3
10	Feb. 12	Oil 1½% and dry-mix 1.33 lbs. (DNOCHP 7.4 oz.)	1,061	3.0	95.8
11	Feb. 12	Oil 2% and dry-mix 1.76 lbs. (DNOCHP 9.9 oz.)	1,268	0.8	98.8
12	Feb. 12	Oil 2½% and dry-mix 2.06 lbs. (DNOCHP 11.5 oz.)	1,318	1.5	97.9
13	Feb. 12	Oil 3% and tar distillate 2%	446	4.9	93.2
14	Feb. 12	Oil 3% and tar distillate 2½%	224	4.0	94.4
15	Feb. 12	Oil 4.6% and lauryl rhodanate 0.4%	368	15.2	79.0
16	Feb. 12	Oil 3% and lauryl rhodanate 0.4%	309	13.5	81.4
17	Feb. 12	Oil 2% and lauryl rhodanate 0.4%	353	46.7	35.7
18	Feb. 12	Oil 2% and lauryl rhodanate 1%	386	1.5	97.9
19	March 5	Oil 3% and dried tar 8 lbs.	374	67.0	7.8
20	March 5	Dried tar 8 lbs.	316	63.9	12.1
		Check, not sprayed	143	72.7	
	1937	*Cooper Orchard*			
21	Nov. 29	Oil 2½% and tar distillate 2%	1,224	2.9	93.1
22	Nov. 29	Oil 3% and tar distillate 2½%	1,165	0.6	98.5
23	Nov. 30	Oil 3% and lauryl rhodanate 0.2%	1,139	5.7	86.5
24	Nov. 30	Oil 2% (DNOCHP 9.8 oz.)	289	2.0	93.2
25	Nov. 30	Oil 3% and lauryl rhodanate 0.4%	475	1.4	96.6
26	Dec. 18	Oil 1½% and lauryl rhodanate 0.1%	308	35.7	15.8
27	Dec. 18	Oil 1½% and lauryl rhodanate 0.2%	319	22.2	47.6
28	Dec. 18	Oil 1½% and lauryl rhodanate 0.3%	1,444	33.7	20.5
29	Dec. 18	Oil 3% and lauryl rhodanate 0.4%	693	4.7	88.9
30	Dec. 18	Oil 3% and lauryl rhodanate 0.2%	645	13.0	69.3
31	Dec. 18	Oil 2% and lauryl rhodanate 0.4%	673	15.6	63.2
32	Dec. 18	Oil 1% (DNOCHP 4.9 oz.)	332	0.9	97.8
	1938				
33	March 3	Wettable DN .63 lb. (DNOCHP 9.5 oz.)	1,433	0.3	99.2
34	March 3	Wettable dry-mix 1.76 lbs. (DNOCHP 9.8 oz.)	633	1.2	97.1
35	March 3	No. 2 soluble oil 2½% and wettable DN 0.63 lb. (DNOCHP 9.5 oz.)	1,137	1.4	96.6
36	March 3	83% oil emulsion 3% and wettable DN 0.63 lb. (DNOCHP 9.5 oz.)	1,471	5.8	86.3
37	March 3	Oil 1% (DNOCHP 4.9 oz.)	651	1.9	95.5
38	March 3	Oil 1½% (DNOCHP 7.35 oz.)	1,212	1.8	95.7
39	March 3	Oil 2% (DNOCHP 9.8 oz.)	1,434	0.0	100.0
40	March 3	Oil 1½% and lauryl rhodanate 0.1%	1,268	34.3	19.1
41	March 3	Oil 1½% and lauryl rhodanate 0.2%	754	8.8	79.2
42	March 3	Oil 1½% and lauryl rhodanate 0.3%	1,224	5.2	87.7
43	March 3	Oil 3% and lauryl rhodanate 0.1%	1,382	21.9	48.3
44	March 3	Oil 3% and lauryl rhodanate 0.2%	1,860	4.6	89.1
45	March 3	Oil 3% and lauryl rhodanate 0.3%	1,663	4.5	89.3
46	March 3	Oil 3% and lauryl rhodanate 0.4%	919	1.0	97.6
47	March 3	Oil 2% and lauryl rhodanate 0.4%	1,002	2.4	94.3
48	March 12	No. 2 soluble oil 2% and wettable D-29 1 lb. (DNOCHP 8.0 oz.)	1,671	0.0	100.0
49	March 12	No. 3 soluble oil 2% and wettable D-29 1 lb. (DNOCHP 8.0 oz.)	2,953	0.0	100.0
50	March 12	No. 3 soluble oil 3% and lauryl rhodanate 0.4%	844	0.0	100.0
		Check, not sprayed	1,791	42.4	
	1937	*Round Hill Orchard*			
51	Dec. 2	Oil 3% and lauryl rhodanate 0.4%	2,033	27.0	26.8
52	Dec. 2	Oil 3% and lauryl rhodanate 0.2%	1,072	30.6	17.0
53	Dec. 2	Oil 2½% and tar distillate 2%	1,498	5.6	84.8
54	Dec. 2	Oil 2% (DNOCHP 9.8 oz.)	624	4.8	86.9
	1938				
55	March 2	Oil 3% and lauryl rhodanate 0.2%	1,042	0.09	99.7
56	March 2	Oil 3% and lauryl rhodanate 0.4%	350	0.0	100.0
57	March 2	No. 2 soluble oil 3% and lauryl rhodanate 0.4%	429	0.0	100.0
58	March 2	Oil 2½% and tar distillate 2%	1,383	1.6	95.6
59	March 2	Oil 2% (DNOCHP 9.8 oz.)	599	0.0	100.0
60	March 2	Wettable DN 0.63 lb. (DNOCHP 9.5 oz.)	668	0.14	99.6
		Check, not sprayed	1,057	36.9	
	1938	*Glaize Orchard*			
61	March 19	Wettable D-27 1¼ lbs. (DNOCHP 7.56 oz.)	12,722	0.08	99.7
		Check, not sprayed	4,543	36.47	

parable to control obtained with other ways of using the toxic material at about the same concentrations. The toxic material in a wettable powder was added to diluted sprays of soluble oil (nos. 35, 48 and 49) and gave control ranging from 96.6 to 100.0 per cent, but when added to an oil emulsion containing sodium caesinate emulsifier the control (no. 36) was 86.3 per cent. In one orchard some trees were sprayed with wettable dinitro-o-cyclo-hexylphenol diluted to contain about 7.4 ounces of the toxic material in 100 gallons. The application was made in clear, mild weather only a couple of days before the eggs were due to hatch. The

results (no. 61) indicated 99.7 per cent control, but on the unsprayed checks in this orchard only slightly more than one-third of the eggs hatched.

LAURYL RHODANATE.*—In most tests the lauryl rhodanate was mixed with petroleum oil before the latter was emulsified. In no. 50, however, lauryl rhodanate was added to a soluble oil without affecting miscibility of the oil when diluted in water. In no. 57 an emulsified lauryl rhodanate was used according to the data in table 2. Lauryl rhodanate at 0.4 per cent by volume in a 3 per cent oil spray applied in March resulted in an average control of 99.4 per cent (nos. 46, 50, 56 and 57). In no. 47 the reduction in volume of oil to 2 per cent was accompanied by a slight reduction in control. Lowering the concentration below 0.4 per cent lauryl rhodanate reduced the efficiency of the ovicide to a marked degree, and fall applications at 0.4 per cent (nos. 25, 29, 31 and 51) usually resulted in a rather low percentage of control, the one exception being no. 25, which resulted in 96.6 per cent control. It has been pointed out elsewhere that the excessive run-off caused by the emulsifier in nos. 15 and 18 was a factor in lowering the control obtained in these tests.

Although lauryl rhodanate at 0.4 per cent strength was very toxic to aphid eggs when applied in March, it should be mentioned that this material is very toxic to fruit buds and somewhat less toxic to leaf buds. In all orchard experiments where lauryl rhodanate was used during the past two seasons, injury to the buds was evident. Even at a concentration of only 0.2 per cent lauryl rhodanate many buds were killed, others were delayed in opening, and on trees of the York Imperial variety there gradually appeared a large number of abnormally small leaves.

FALL VERSUS SPRING APPLICATIONS.—Attention is called to the fact that 2 per cent tar distillate applied in late November or early December (nos. 5, 21, 53 of table 2) was not so toxic to aphid eggs as when applied in March. It also appears that dinitro-o-cyclo-hexylphenol up to about 7.4 ounces in 100 gallons of diluted oil spray was usually less effective in fall applications (average control 90.5 per cent for nos. 1, 2 and 32) than when applied in March (average control 95.5 per cent for nos. 37 and 38 of table 2). According to our experience, tar distillate at 2.5 per cent has given about the same control in fall and spring applications. It will be observed that oil containing dinitro-o-cyclo-hexylphenol at 9.5 ounces or more per 100 gallons gave an average control of 94.1 per cent in fall applications involving four tests (nos. 3, 4, 24 and 54), and that in three of these the control was above 95.0 per cent but dropped to 86.9 per cent in the fourth test (no. 54), which was made in cold, windy weather. In the only two similar tests made in March (nos. 39 and 59) the control was 100 per cent.

Failure of the lighter concentrations of the ovicides to give control in the fall applications equal to control resulting from the spring applications appears to be due to loss of the toxic substance through weathering. It is known (Baker & Turner 1916; Peterson 1918) that eggs of apple aphids in the fall are in a resting or dormant stage which is not broken before

Table 3.—Emulsifier employed in oil emulsions used in tests of 1936 to 1938.

EMULSIFYING INGREDINTS IN 100 GALLONS OF DILUTED SPRAY	PREPARATIONS IN WHICH EMULSIFIERS WERE USED
4 oz. *Goulac* and 12 oz. bentonite	Nos. 1, 2, 3, 4, 26, 27, 28, 29, 30, 31 and 32 of table 2
4.5 oz. *Goulac* and 4.5 oz. bentonite	No. 9 of table 2
5 oz. *Goulac* and 15 oz. bentonite	Nos. 37, 38, 39, 40, 41, 42, 43, 44, 45, 46 and 47 of table 2
6 oz. *Goulac* and 10 oz. bentonite	Nos. 23, 24, 25, 51, 52, 54, 55, 56 and 59 of table 2
6.9 oz. *Goulac* and 6.9 oz. bentonite	No. 10 of table 2
9.1 oz. *Goulac* and 9.1 oz. bentonite	No. 11 of table 2
10 oz. *Goulac* and 10 oz. bentonite	Nos. 7, 8, 13, 14, 15, 16, 17, 18, 19 and 20 of table 2
10.7 oz. *Goulac* and 10.7 oz. bentonite	No. 12 of table 2
A prepared emulsion	Nos. 5, 6, 21, 22, 53 and 58 of table 2

* Chief component dodecyl thiocyanate but also contained octyl, decyl and tetradecyl thiocyanate.

the eggs have been exposed to low temperatures for some time. Eggs not exposed to low temperatures fail to hatch. It appears as though the toxic substance of the ovicide may not be effective before the dormant stage of the egg is broken and, in order to be effective, ovicides applied during the fall must adhere to the egg in lethal quantities until the egg is susceptible to the toxic substance. Some branches from the trees which received the various concentrations of ovicides on November 25, 1936, (nos. 1 to 6 of table 2) were brought to the insectary immediately after the spray had dried. These branches were exposed to outdoor temperatures through the winter but were sheltered from precipitation. Dinitro-o-cyclo-hexylphenol at the minimum dosage of 4.9 ounces per 100 gallons gave 97.4 per cent control on the eggs sheltered from precipitation through the winter while the same treatment on the eggs remaining in the orchard resulted in 84 per cent control (no. 1 of table 2). Tar distillate at 2 per cent strength gave 99.1 per cent control on eggs kept in the shelter compared to 90.5 per cent control in the orchard (no. 5 of table 2). Tar distillate at 2.5 per cent strength on the eggs brought to the insectary in November gave 99.1 per cent control while dinitro-o-cyclo-hexylphenol at 7.4, 9.8 and 11 ounces per 100 gallons each gave 100.0 per cent control on the eggs protected from precipitation. In this series of experiments the important factor in determining the control obtained with the lighter concentrations was whether or not the sprayed eggs remained exposed to normal precipitation through the winter.

An apparent exception occurred in test no. 37 on December 18, 1937, when 1 per cent oil and 4.9 ounces of dinitro-o-cyclo-hexylphenol in 100 gallons gave 97.8 per cent control in the orchard. It is possible that an unusually heavy deposit of the toxic material occurred in this particular application. But certain weather factors should also be taken into consideration; namely, only 2.6 inches of rain fell from the date of application through February, whereas in the previous season 12.6 inches were recorded from the date of the fall application through February. It is also noteworthy that the eggs sprayed on December 18, 1937, had already been exposed to cold weather of unusual severity for early December in this section of the country, as is indicated by the fact that the mean daily temperature was above freezing on only 3 days out of 15 days immediately preceding the date of spraying.

DISCUSSION.—It is apparent that each of the materials under test, except the dried tar, was toxic to the aphid eggs. Phytocidal action has not been definitely established for each material, but our experience with lauryl rhodanate indicates that it is too toxic to fruit buds for further consideration. This compound also killed many leaf buds in the spring applications. Dinitro-o-cresol, its sodium salt and dinitro-o-cyclo-hexylphenol appear to be comparatively safe on dormant trees under our conditions. Such injury as has occurred in four years with the first two compounds and in three years with the last named compound can be attributed to the use of improperly mixed ingredients resulting in the application of excessive concentrations on parts of the trees or to applying the sprays when green bud tips were showing. At the concentrations used the dinitro compounds are very toxic to buds in the delayed dormant stage.

SUMMARY.—Dinitro-o-cresol, its soluble salt sodium dinitro-o-cresylate, dinitro-o-cyclo-hexylphenol and lauryl rhodanate are effective ovicides for aphid eggs occurring on apple trees. These compounds compared favorably with coal-tar distillate in their ovicidal action on aphid eggs.

Sodium dinitro-o-cresylate (dinitro-o-cresol at 2.5 to 2.9 pounds per 100 gallons) was effective when applied in January, February or March.

Dinitro-o-cyclo-hexylphenol in oil was effective in fall and spring applications when used at concentrations of not less than 9.5 ounces per 100 gallons of diluted spray. Lighter concentrations (4.9 to 7.4 ounces) in fall applications usually gave inadequate control.

Dinitro-o-cyclo-hexylphenol in water suspensions showed high toxicity to aphid eggs when applied in March.

Lauryl rhodanate was toxic to aphid eggs and also to apple buds. Its phytocidal action was sufficiently severe to eliminate it from further consideration.
—11-18-38.

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Effect of Copper Fungicides on Lead-Arsenate-Lime and Fixed Nicotine-Oil Sprays for Codling Moth

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In the spring of 1938, the Departments of Plant Pathology, Chemistry and Entomology of the Delaware Agricultural Experiment Station entered upon a cooperative orchard spraying investigation. It was planned to study, first, various fungicidal and insecticidal combinations commonly applied on apple in the state, with the immediate objective of developing a spraying program effective in control of diseases and insects and at the same time productive of a crop with a minimum amount of russeted fruit. Frequently, the percentage of culls with blemishes caused either by the spray materials employed or by the conditions of application has been sufficiently high so that the loss in this respect has practically offset the increase in worm-free and otherwise uninjured apples. The present paper summarizes results and conclusions at the end of the first season's work with special reference to the control of codling moth.

METHOD.—A block of 21-year old interplanted Jonathan and Stayman apples in the W. L. Smith Orchard, Cheswold, Del., is being utilized in this investigation. In 1938, the experimental program included 32 treatments, 22 of which are considered herein. In most cases, provision was made for three replicates comprising two trees of each of the varieties represented. However, data involving 144,638 dropped and harvested apples were recorded for Jonathan only, since the Stayman crop was very light.

Sprays were applied with a new *Bean* sprayer of 300 gallons capacity, with a rated discharge of 20 gallons per minute and operating at approximately 500 pounds pressure. Two four-nozzle brooms were used, both of which were handled from the ground, an entire tree being sprayed by each man.

The schedule of applications is detailed in table 1. It included a delayed dormant spray, 2 pre-bloom sprays, a full bloom spray, a petal fall spray and 10 cover sprays, 6 for the first brood of codling moth spaced at approximately seven-day intervals and 4 for the second brood, each about 12 days apart.

In so far as insecticides are concerned, the several treatments under test were identical up to and including the first cover spray. All of the plots received a delayed dormant spray of oil emulsion and tar oil, with no fungicide, and, in the petal fall and first cover sprays, lead arsenate and hydrated lime. In all of the

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Table 1.—Spraying program on Jonathan apple, W. L. Smith orchard, Cheswold, Del., 1938.

Treatments or Plots	Petal Fall Spray April 25*	First Brood Cover Sprays						Second Brood Cover Sprays			
		First May 9	Second May 23	Third May 31	Fourth June 8	Fifth June 15	Sixth June 23	Seventh July 13	Eighth July 25	Ninth August 6	Tenth August 16
26	FSP16	FSP12	—	—	—	Untreated check					
1	LLS 2 L&L 3&5	LLS 2 L&L 3&5	L&L 3&5	—	—	Same in all other cover sprays					
2-3-5	LLS 2 or FSP16 L&L 3&5	LLS 2 or FSP12 L&L 3&5	B 3–5 L 3	—	—	Same in all other cover sprays					
12	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 L&L 3&5	—	—	Same in all other cover sprays					
11	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 6 L&L 3&5	—	—	Same in all other cover sprays					
6	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 L&L 3&5	—	—	Same in all other cover sprays					
10	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 L&L 3&5	—	—	Same in all other cover sprays					
9	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 1 L&L 3&5	—	—	Same in all other cover sprays					
8	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 3 L&L 3&5	—	—	Same in all other cover sprays					
7	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 1½ L&L 3&5	—	—	Same in all other cover sprays					
16	LLS 2 L&L 3&5	LLS 2 L&L 3&5	*BL* 8	—	—	Same in all other cover sprays					
15	LLS 2 L&L 3&5	LLS 2 L&L 3&5	*BL* 8	*BL*6, 0♀	*BL*4, 0♀	Same in all other cover sprays					
17	FSP16 L&L 3&5	FSP12 L&L 3&5	B 3–5 *BL* 8	B 3–5 *BL*6, 0♀	B 3–5 *BL*4, 0♀	Same in all other cover sprays					
23	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 6 *BL* 8	CF 6 *BL*6, 0♀	CF 6 *BL*4, 0♀	Same in all other cover sprays					
22	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 *BL* 8	CF 2 *BL*6, 0♀	CF 2 *BL*4, 0♀	Same in all other cover sprays					
18	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 *BL* 8	CF 2 *BL*6, 0♀	CF 2 *BL*4, 0♀	Same in all other cover sprays					
19	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 1½ *BL* 8	CF 1½ *BL*6, 0♀	CF 1½ *BL*4, 0♀	Same in all other cover sprays					
20	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 3 *BL* 8	CF 3 *BL*6, 0♀	CF 3 *BL*4, 0♀	Same in all other cover sprays					
21	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 1 *BL* 8	CF 1 *BL*6, 0♀	CF 1 *BL*4, 0♀	Same in all other cover sprays					
24	FSP16 L&L 3&5	FSP12 L&L 3&5	CF 2 *BL* 8	CF 2 *BL*6, 0♀	CF 2 *BL*4, 0♀	Same in all other cover sprays					

* Delayed dormant spray, March 29; pre-bloom sprays, April 5 and 13; full bloom spray, April 22.

FSP = flotation sulfur paste; LLS = liquid lime sulfur; B = Bordeaux; CF = any proprietary insoluble copper fungicide; L = lead arsenate; L&L lead arsenate and hydrated lime; *BL* = *Black Leaf 155;* and O = summer oil. All materials, except liquid lime sulfur (2 gallons) and summer oil (2 quarts), are expressed as pounds in 100 gallons of water.

early sprays (pre-bloom, full bloom, petal fall and first cover), treatments varied, however, in respect to the fungicide included (liquid lime sulfur, flotation sulfur or a combination of the two), a factor obviously of little or no significance in codling moth control.

Marked differentiation in treatments commenced with the second cover spray. Two comparable series of plots were established at that point for continuance throughout the remainder of the season: first, a lead arsenate plus lime series with this insecticide alone and in combination with Bordeaux mixture and with seven proprietary insoluble copper compounds, including *ZO*, *OXO-Bordeaux*, *Coposil*, *Copper Hydro*, *Basi-Cop*, *Cupro-K* and *Compound A;* and second, a fixed nicotine plus oil series with *Black Leaf 155* alone, with oil and in combination with the copper fungicides mentioned above. All of the commercial products were used in accordance with the recommendation of the manufacturer (refer to table 1 for rates and other details).

Table 2.—Results of spraying program on Jonathan apple, W. L. Smith orchard, Cheswold, Del., 1938.

Treatments or Plots	Per Cent of Both Dropped and Harvested Fruit			Number Per 100 Apples			Residue on Leaves Micrograms Per Square Inch						Correction of Arsenical Injury	Release of Nicotine	Amount of Russet‡
	Clean	Wormy	Stung	Worms	Stings	Total Injuries	Arsenic*		Copper†		Nicotine**				
							(1)	(2)	(3)	(4)					
26	5.8	88.6	5.6	151.1	18.0	169.1	Trace	Trace	Trace	Trace			Untreated check	—	Negligible
1	50.8	14.7	34.5	18.4	77.2	95.6	202.1	303.0	Trace	Trace			Negligible	—	Moderate
2-3-5	71.1	8.9	20.0	11.7	36.0	47.7	236.8	328.2	159.8	173.1			Excellent	—	Moderate
12	37.3	29.1	33.6	48.4	104.3	152.7	130.6	155.5	31.9	50.2			Slight	—	Light
11	38.8	22.2	39.0	38.4	120.3	158.7	147.8	181.9	57.1	85.7			Very Good	—	Light
6	39.3	22.2	38.5	34.4	126.3	160.7	188.1	200.7	55.7	71.5			Slight	—	Light
10	43.1	16.0	40.9	25.6	86.7	112.3	169.5	189.7	49.8	67.7			Good	—	Light
9	44.7	16.5	38.8	23.9	89.5	113.4	171.1	242.6	44.9	63.1			Slight	—	Light
8	46.5	16.8	36.7	24.3	90.6	114.9	169.5	177.3	80.6	102.5			Good	—	Very light
7	46.9	16.4	36.7	21.0	89.7	110.7	181.5	208.5	44.8	61.0			Good	—	Light
Average for above 7	*42.4*	*19.9*	*37.7*	*30.9*	*101.0*	*131.9*	*165.5*	*193.7*	*52.1*	*71.7*			*Variable*	—	*Light*
											(5)	(6)			
16	46.1	40.4	13.5	60.0	31.3	91.3	—	—	Trace	Trace	1.11	2.52	—	—	Moderate
15	50.5	38.2	11.3	55.4	24.5	79.9	—	—	Trace	Trace	0.85	2.39	—	—	Light
17	33.8	44.9	21.3	76.1	52.4	128.5	—	—	147.6	193.4	0.07	0.92	—	Very Rapid	Moderate
23	35.7	52.0	12.3	85.4	84.5	119.9	—	—	59.1	102.6	Trace	0.69	—	Very Rapid	Moderate
22	43.2	42.5	14.3	64.5	32.0	96.5	—	—	79.7	105.5	0.30	1.50	—	Partial	Moderate
18	45.1	43.6	11.3	61.3	27.3	86.6	—	—	90.6	116.4	0.51	1.77	—	Partial	Severe
19	45.5	46.9	7.6	73.5	21.0	94.5	—	—	71.7	113.1	0.68	2.19	—	Slow	Severe
20	49.6	37.0	13.4	53.4	30.2	83.6	—	—	152.5	194.7	0.69	2.19	—	Slow	Moderate
21	53.0	40.0	7.0	51.3	14.6	65.9	—	—	119.8	164.7	0.89	2.44	—	Negligible	Severe
24	59.0	33.1	7.6	44.6	16.6	61.2	—	—	75.3	107.2	0.57	2.36	—	Very Slow	Severe
Average for above 7	*47.3*	*42.2*	*10.5*	*62.0*	*25.2*	*87.2*	—	—	*92.7*	*129.2*	*0.52*	*1.88*	—	*Variable*	*Severe*

* Arsenic as As_2O_3; analyses by M. W. Goodwin; figures are average of duplicate samples taken (1) before and (2) after last cover spray on August 16.
† Analyses by M. W. Goodwin; figures are average of samples taken (3) before and (4) after each cover spray.
** Analyses, courtesy of Tobacco By-Products and Chemical Corporation, Louisville, Ky.; figures are average of samples taken (5) before and (6) after each cover spray.
‡ Estimated periodically throughout season and at harvest, September 6.

RESULTS.—The results in 1938 for the Jonathan variety are summarized in table 2. Complete data are presented in respect to codling moth control and arsenic, copper and nicotine analyses and, also, observational records covering the degree of correction of arsenical injury, the release of nicotine and the amount of russet. Scab and other diseases were of no importance and consequently information on fungicidal efficiency is lacking.

It is apparent from the records in table 2 that the natural infestation of codling moth was extremely high, since but 5.8 per cent of both dropped and harvested fruit in the case of the untreated check (plot 26) was free from injury by this insect.

In the lead arsenate plus lime series, treatment 1 (lead arsenate, 3 pounds, and hydrated lime, 5 pounds) produced 50.8 per cent clean fruit. The combination of lead arsenate (3 pounds) and Bordeaux mixture (3–5) (plots 2, 3 and 5) proved most effective, with as high as 71.1 per cent of the crop uninjured. The correction of arsenical injury was excellent and the amount of russet from light to moderate and largely attributable to the combination of liquid lime sulfur, lead arsenate and lime applied in the petal fall and first cover sprays (plot 2). No discrimination seems advisable in the matter of the comparative efficiency of the several insoluble copper compounds. When the copper compounds were used at the recommended rates in combination with lead arsenate (3 pounds) and hydrated lime (5 pounds), the average per cent of clean fruit for the group (treatments 6 to 12, inclusive) was 42.4, or 28.7 per cent less than recorded for the Bordeaux plus lead arsenate treatment. Correction of arsenical injury was variable—from slight to very good—and the amount of russet generally and favorably light. The lower efficiency, however, of these insoluble copper fungicides is undoubtedly due to the physical characteristics of spray mixtures of such compounds, which are unable to produce desirably high deposits of copper and arsenic on foliage and fruit. Their inability in this particular is evident in the following comparative figures for analyses of residue on leaves subsequent to the final cover spray expressed as micrograms per square inch: Bordeaux with lead arsenate (plots 2, 3 and 5) plus copper (173.1) and arsenic (328.2); average for insoluble copper compounds with lead arsenate (plots 6 to 12, inclusive) plus copper (71.7) and arsenic (193.7).

Results in the fixed nicotine plus oil series were very unsatisfactory. *Black Leaf 155* (8 pounds) alone (treatment 16) produced 46.1 per cent clean fruit. With oil (2 quarts) and used on the recommended, decreasing 8-6-4 basis (plot 15), it was slightly more effective (50.5 per cent), but, when combined similarly with oil and with Bordeaux mixture (3–5) (plot 17), it was decidedly less effective (33.8 per cent). The average per cent of clean fruit for the insoluble copper compounds with *Black Leaf 155* and oil (treatments 18 to 24, inclusive) was 47.3, control somewhat better (4.9 per cent) than that previously noted for the same products with lead arsenate. But 19.9 per cent, however, of the fruit in the case of the insoluble coppers plus lead arsenate group was wormy as compared with 42.2 per cent for that from the insoluble coppers plus fixed nicotine plus oil plots. Furthermore, in the latter instance, the amount of russet—moderate to severe—was sufficiently great so that a high percentage of the crop fell within the unclassified grade. The only favorable comment, in fact, that can be made concerning the performance of the several treatments comprising the fixed nicotine plus oil series in the present experiment is that, without exception, they gave effective control of the unspotted tentiform leaf miner, *Parornix prunivorella* Cham., under conditions of severe infestation (foliage of untreated check trees averaging 1.8 mines per leaf).

SUMMARY.—The data presented herein and other results for the season of 1938 would seem to indicate that an apple spraying program (with, of course, certain varietal limitations), including pre-bloom applications of liquid lime sulfur (or possibly a combination of liquid lime sulfur and flotation sulfur), with flotation sulfur, lead arsenate and hydrated lime in the petal fall and first cover sprays, followed by successive applications of a relatively weak Bordeaux mixture with lead arsenate, is best designed to meet the exacting requirements of effective control of diseases and insects under Delaware conditions without serious spray injury on foliage and fruit.—11-17-38.

Dormant Spray Problems in New York*

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There are a number of problems which confront entomologists who desire to recommend dormant treatments for apple, pear and cherry insects. These problems fall under two main divisions: (1) materials and mixtures, and (2) the question of fall versus spring applications as regards materials and mixtures. The more important information needed includes efficiency on insects, degree of control necessary, safeness to trees and sprays that will control a number of species with a single application. The object of this paper is to give a summary of results secured with various materials on these phases of control in relation to some of the more important fruit insects. Since results on only those insects whose control has been studied by the writer are included, the discussion does not give a complete picture of all the dormant spray problems in New York. Additional fruit pests are under investigation by other members of the station staff. Insects whose control by dormant treatments has been studied by the writer, and the hosts involved, are the following: *apple*—rosy aphid, *Anuraphis roseus* (Baker); eye-spotted budmoth, *Spilonota ocellana* (D. & S.); oystershell scale, *Lepidosaphes ulmi* (L.); and San José scale, *Aspidiotus perniciosus* Comst.; *pear*—pear psylla, *Psylla* (*Psyllia*) *pyricola* (Foerst.); *cherry*—black cherry aphid, *Myzus cerasi* (F.).

Materials and Mixtures.—Limitation of space prevents the consideration of the large number of materials, mixtures and concentrations tested. With a few exceptions as regards concentrations, only those dormant sprays will be discussed that have been found relatively safe as spring applications on vigorous trees at concentrations effective for certain insects. They include lime sulfur, lubricating oil, nicotine, coal tar oil, tar oil plus lubricating oil, DN-oil, and *Elgetol*.† A number of the concentrations used are given in table 1.

Of these materials, lime sulfur, nicotine and lubricating oil, suitable for dormant spraying, need no further comment. Coal-tar oil (frequently mentioned only as tar oil in this discussion) has been under investigation at the Geneva Station since 1929. As the American brands used until about 1934 generally contained lubricating oil, which was maintained at a constant amount in a particular brand, but varied between brands (Hartzell & Pearce 1934; Hartzell, Harman & Reed 1935), only data secured since 1934 with standardized materials are given. The same is true regarding tar oil plus lubricating oil. DN-oil is a shortened term for lubricating oil in which is dissolved dinitro-o-cyclohexylphenol (abbreviated DN)—96 parts of oil by weight to 4 parts of DN. The first experiments by the writer with DN-oil were made in 1936 and are being continued. In 1936 the material was supplied in three forms: a mayonnaise type of emulsion and two miscible oil mixtures which differed only in the material used to make the oil miscible with water. In 1937 the mayonnaise type was marketed under the name of *Dowspray Dormant*.‡ In order to avoid trouble caused by freezing, *Dowspray Dormant* in 1938 was sold as a solution of DN in oil, but the emulsifier was furnished separately. Various other forms of this mixture have been tested. Since these various types at the same concentrations, both as regards oil and DN, were of about equal efficiency on the insects mentioned in table 1, the percentage reductions have been averaged.

Elgetol is a relatively new material in this country. It is a water soluble mixture that is claimed to consist of a salt of dinitro-cresol and other ingredients. As the first tests by the writer were made in 1937 to determine its safeness to trees, the control data regarding *Elgetol* are from experiments made in 1938. More testing is necessary to determine whether or not this promising preparation will maintain its high efficiency on oystershell scale and budmoth, but especially to learn its value for the control of rosy

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† Manufactured by Standard Chemical Products, Inc., Hoboken, N. J.

‡ Manufactured by the Dow Chemical Company, Midland, Mich.

aphid and San José scale. Lubricating oil, 6 per cent, alone or combined with nicotine was first tested against budmoth in 1938. Unfortunately the scarcity of rosy aphid throughout western New York in 1938 prevented the securing of data relative to its control by *Elgetol;* lubricating oil, 6 per cent; or lubricating oil, 6 per cent, with nicotine sulfate, 1 to 400.

EFFICIENCY ON INSECTS.—The data on control of a particular species with a definite mixture in table 1 usually are averages of percentage reductions from a number of tests conducted under different conditions as regards orchards, varieties and years. The averages of control for San José scale and pear psylla by lime sulfur were secured more than a decade ago from extensive field tests that have not been repeated since and are introduced to serve for comparisons with the more efficient materials available today.

For various reasons opportunity was not afforded to use the same number of trees for the tests with each mixture on each of the six species mentioned previously. As a rough index of the reliability of the different averages, the number of count trees, on which each mean is based, has been placed in parentheses following that average. Neither the number of count trees nor probable errors would give an accurate measure of the reliability of the averages; in fact probable errors are liable to misinterpretation. For example, suppose tests of two sprays were made and averages computed on 20 count trees for each mixture. If in the test of the first mixture all the trees were from one orchard, while in the test of the second material the trees not only were from separate orchards but the trials were made during different years (even though the probable error of each mean was identical), the reliability of the average of the effectiveness for the second mixture would be considerably greater than that of the first as a basis for recommendations to fruit growers because of the fact that the second mixture was tested under a greater variety of conditions.

It will be noted that the number of count trees is not given for the means of the tests on San José scale nor for the effect of lime sulfur on pear psylla. This is due to the fact that the sampling for San José scale was not made on a tree but on a plat basis and that, in the case

Table 1.—Summary of results with certain dormant sprays during 1936, 1937 and 1938.

MATERIALS	SAN JOSÉ SCALE PER CENT REDUCTION	OYSTER-SHELL SCALE PER CENT REDUCTION	ROSY APPLE APHID PER CENT REDUCTION	BUDMOTH PER CENT REDUCTION	BLACK CHERRY APHID PER CENT REDUCTION	PEAR PSYLLA PER CENT REDUCTION
Lime sulfur 1–8	85.0*	64.5 (1)	—	—	—	62.0*
Lubricating oil 2%	98.8	—	—	—	—	86.7 (17)
Lubricating oil 3%	100.0	—	—	25.5 (13)	—	95.5 (17)
Lubricating oil 6%	—	—	—	87.3 (3)	—	—
Lubricating oil 6%+nicotine sulfate 1–400	—	—	—	93.6 (2)	—	—
Coal-tar oil 2%	—	—	—	—	98.0 (2)	98.5 (16)
Coal-tar oil 2½%	—	—	96.7 (13)	59.1 (3)	—	—
Coal-tar oil 3%	—	87.3 (2)	—	73.1 (10)	—	97.6 (16)
Coal-tar oil 3¼%	—	90.3 (4)	—	63.6 (28)	—	—
Coal-tar oil 4½%	—	90.9 (28)	90.2 (32)	73.5 (27)	—	—
Coal-tar oil 5½%	—	—	89.5 (7)	—	—	—
Tar oil 2½%+lubricating oil 3%	—	99.9 (2)	92.3 (24)	85.4 (28)	—	—
Tar oil 3%+lubricating oil 2½%	—	94.6 (4)	—	75.1 (12)	—	—
DN-oil 1½%	—	—	68.8 (10)	83.7 (10)	100.0 (2)	98.5 (16)
DN-oil 2%	100.0	—	93.6 (16)	93.4 (32)	96.0 (2)	96.8 (49)
DN-oil 2½%	—	—	—	95.5 (13)	—	—
DN-oil 3%	100.0	92.5 (5)	92.0 (25)	96.3 (74)	100.0 (2)	99.7 (18)
DN-oil 4%	—	94.6 (25)	95.0 (6)	96.3 (32)	—	—
Elgetol 1%	—	97.9 (3)	—	98.4 (7)	—	—
Elgetol 1½%	—	100.0 (2)	—	99.0 (18)	—	—
Elgetol 2%	—	99.8 (2)	—	99.0 (19)	—	—

* Average secured from data taken previous to 1936.

of this single pear psylla average, all the counts were made on spurs taken at random throughout each treated and check plat.

The infestations of San José scale, pear psylla, rosy and cherry aphids were very light on the check trees throughout the course of these experiments. In fact, a large number of tests were made in vain because of the impossibility of predicting the abundance of aphids. Fortunately, since budmoth was present, in some of these orchards the treatments were not always a total loss.

Before discussing the effectiveness of the various treatments it is necessary to consider the degree of control necessary to afford practical protection to a fruit crop or to the trees in the cases of oystershell scale and pear psylla. Because the export trade demands apples almost free from evidence of San José scale, the material should give about 100 per cent reduction of this insect. In the case of oystershell scale a material should give a reduction of at least between 70 and 80 per cent for a light to moderate infestation; 80 to 90 for a severe infestation; but for very severe infestations, the control should approximate at least 90 per cent reduction in infestation. For rosy apple aphid and black cherry aphid a minimum control of 85 per cent efficiency is demanded for severe outbreaks, and 90 per cent or greater would be advantageous. In cases of severe infestations by pear psylla a minimum control of 94 per cent is usually necessary to protect the trees, although for moderate numbers of psylla a control of 85 per cent would probably be sufficient for protection. The efficiencies required to control budmoth have a wider range. Where there are light infestations, efficiencies between 60 to 70 per cent usually will prevent the insect from becoming more abundant. For heavier infestations the control should approximate the following: moderate, 70 to 85; severe, 85 to 95; and very severe, 95 to 100 per cent efficiency.

Referring to table 1, it will be noted that the following minimum dosages are required to approximate the control mentioned in the preceding paragraph: San José scale, lubricating oil 3 per cent, or DN-oil 2 per cent; oystershell scale, (severe) tar oil 3 per cent, and possibly DN-oil 2½ per cent; (very severe) tar oil 4½ per cent, tar plus lubricating oil (either the 2½ to 3 or the 3 to 2½ mixture) 5½ per cent, DN-oil 3 per cent or *Elgetol* 1 per cent; rosy aphid, tar oil 2½ per cent, tar plus lubricating oil (2½ to 3 mixture) 5½ per cent, DN-oil 2 per cent; cherry aphid, tar oil 2 per cent, and DN-oil probably 1½ to 2 per cent; budmoth (light to moderate) tar oil 4½ per cent, tar plus lubricating oil (either mixture) 5½ per cent; (severe) lubricating oil 6 per cent, possibly tar plus lubricating oil 5½ per cent, or DN-oil 1½ per cent; (very severe) lubricating oil 6 per cent with nicotine sulfate 1 quart, DN-oil 2 per cent, and *Elgetol* 1 per cent. A study of table 1 and this paragraph will indicate what materials and concentrations are necessary to control several pests that may be in the same orchard.

SAFENESS TO TREES.—Many factors enter into the problem of setting safe limits of insecticides to trees, the apple, for instance. Health, variety and age are important factors, and of these three health is the most difficult to estimate as much depends on the soil, growing conditions, winter injury (recent or remote), size of the previous crop, etc. Weak trees are more susceptible to injury by certain dormant sprays than are strong trees. Winter-injured trees are especially prone to have this harm increased by certain sprays (Hartzell, Harman & Reed 1935; Hartzell 1936). After the severe drought ending in 1936, trees growing on a sandy southern slope were much more severely injured by certain materials than were trees growing on heavier soil or on level sandy soil. As regards varieties, among trees of the same apparent vigor, McIntosh, Ben Davis, Wealthy, Northern Spy and Twenty Ounce seem to be more susceptible to spray injury than are Baldwin and Rhode Island Greening; at least under New York conditions.

In an attempt to set safe maximum concentrations these more tender varieties are taken into consideration. The concentration of any material could probably be increased by one-fourth with safety for Baldwin and Rhode Island Greening. The concentrations given are for trees that have not suffered from drought during the preceding summer and have not been subjected to extremely low temperatures for the locality during the previous two winters. Furthermore, the figures ap-

ply strictly to western New York and should be used with caution in other regions.

The trees are grouped according to vigor and the maximum concentrations believed to be reasonably safe are as follows: vigorous trees, lubricating oil 5½ per cent, coal-tar oil 5½ per cent, tar plus lubricating oil 5½ per cent, DN-oil 3 per cent, *Elgetol* 2 per cent (higher concentrations not tested); weak trees, lubricating oil 3 per cent, coal-tar oil 5 per cent, tar plus lubricating oil 3 per cent, DN-oil 2 per cent, *Elgetol*, not determined, but 1 per cent produced no injury to certain weak trees on which it was tested in 1937. Petroleum oil sprays are not advised for very weak trees and the use of tar oil is doubtful. DN-oil was used on a few trees at 4, 5 and 6 per cent concentrations. At 4 per cent concentration it caused no injury on most trees, but in a few instances this strength injured the buds of healthy McIntosh trees. Even the 6 per cent concentration did not harm the buds of Baldwin and Rhode Island Greening on some trees, but seriously injured the buds and twigs of other trees of these two varieties. Lubricating oil, 6 per cent, is the standard dormant recommendation for leaf roller in New York. While this mixture generally produces no injury to the buds, there are instances of buds being killed; so the safe dilution is set at 5½ per cent on vigorous trees.

On sweet cherry trees DN-oil has been used at 3 per cent and tar oil at 4 per cent without causing injury, but sufficient tests have not been made to prove that these concentrations are always safe on vigorous trees.

As regards pear trees, moderately vigorous trees tolerated lubricating oil 3 per cent, DN-oil 3 per cent and coal-tar oil 3 per cent. Weak trees were seriously injured by lubricating oil 3 per cent, if the spray was applied more than two years in succession. Tests of tar oil and DN-oil were repeated in 1937 on trees receiving these mixtures in 1936 without detriment to the trees.

FALL VERSUS SPRING APPLICATIONS.—Thus far the discussion has been restricted to spring treatments. The question of fall applications is often raised, but, to date, the writer has advised against this practice for western New York. The reason for this attitude is that it is impossible to predict, at least so far as known, the minimum winter temperatures that will occur, nor can the amount of winter injury to trees be foretold. After the winter of 1933–34, tests proved the inadvisability of using any kind of oil spray on severely injured trees. If sprays containing lubricating oil, not in excess of 3 per cent, or tar oil, not in excess of 3 per cent, are used on moderately vigorous trees, and a normal winter follows, usually, no injury from the spray occurs; so if it were possible to foretell the nature of the winter that will follow, fall applications with these mixtures could be used. On the other hand, if fall treatment is advised and a tree-killing winter occurs, the one who made the recommendation may find himself severely censured by the fruit grower the following summer.

It is well known that fall spraying is a regular practice in the Shenandoah region and that the trees are not injured. The winters, however, are less severe than those in western New York, which probably makes the risk of winter injury much less than in the northern area. This is another illustration of how local in application the results of any investigation may be. Before recommendations are made for other areas the same materials should be carefully tested in the section to which the recommendations are to apply.—11-18-38.

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THE alfalfa weevil quarantines of Colorado were reissued on January 3, 1939, the changes including the designation of 11 entire counties in that state, and parts of 4 others as infested with the weevil.

Control of Apple Aphids and European Red Mite by Coal Tar Oil and Other Materials*

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About five years ago the coal tar creosote emulsions—hereafter referred to as tar oils—came into prominence in this country as dormant spray materials for apple trees. The discovery of their effectiveness against eggs of the rosy apple aphid, *Anuraphis roseus* (Baker), had extended the spraying period for this important pest forward into the dormant season. In Pennsylvania (Worthley 1937), as in other eastern states, results against apple aphids has been uniformly good.

Some doubt has been cast upon the usefulness of the tar oils under Pennsylvania conditions, however, since some of the heaviest infestations of the European red mite, *Paratetranychus pilosus* (C. & F.), have developed in orchards sprayed with tar oil at 2.4 per cent concentration, either alone or in mixture with 3 per cent lubricating oil. In spite of this, the literature to date indicates their effectiveness against several insects and a plant disease, and were it not for their caustic action on the skin of many users they would doubtless now be among the leading dormant spray materials.

Present Uses of Tar Oil Sprays.—In an occasional fortunate instance, tar oil sprays may fail to injure apple buds that have advanced to the "green tip" stage. However, they may be toxic to growing plant tissue at concentrations as low as 0.75 per cent (Hartzell 1933), and should be used only when the buds are strictly dormant. Even then, high concentrations may be injurious. In Virginia, Hough (1933) has reported only slight retardation of the buds with sprays containing upwards of 7 per cent tar oil, while in New York state 6.2 per cent total oil appears to be the safe maximum following normal winter weather (Hartzell 1936). After winters cold enough to injure apple trees, concentrations greater than 5 per cent may produce injury (Hartzell, Harman & Reed 1935).

A second precaution in the use of tar oils is protection of the exposed skin of the operator by greasing (Hough 1933), or by washing with 1 part vinegar in 3 parts water (Hartzell & Parrott 1933). With many persons, however, such measures seem to give but partial protection against burning of the skin, and this caustic property of the tar oils has prevented their more general use. While certain less caustic materials are now challenging the tar oils, reports indicate that the latter may be used successfully, either alone or in mixture with lubricating oil, to combat one plant disease and several insects, as follows:

Apple aphids, 1.8–2.4 per cent actual tar oil (Hartzell & Pearce 1934).

Black cherry aphid, 1.6–1.8 per cent actual tar oil (*ibid.*).

San José scale, 5 per cent tar oil or 3 per cent lubricating oil with or without 3 per cent tar oil (Hough 1933); 2.5 per cent tar oil with 2 per cent lubricating oil (Hurt 1933); 6 per cent tar oil (Stanley, Marcovitch & Andes 1934); with 2.4 per cent tar oil used for aphids, add 3 per cent lubricating oil (Hartzell 1936).

Scurfy scale, 4.5 per cent tar oil (Hammer 1938).

Oystershell scale, 4.5 per cent tar oil plus 1 per cent lubricating oil (Hartzell & Moore 1937).

Eye-spotted budmoth, 70–85 per cent kill with 4.5 per cent tar oil (Hartzell & Pearce 1934).

Pear psylla, 5 per cent tar oil, but 3 per cent lubricating oil preferred (Hartzell & Parrott 1933).

Pine needle scale, 75–82 per cent reduction with 4 per cent tar oil (Gambrell 1938); 36 per cent kill with 5.3 per cent tar oil (Zappe 1938).

Spruce gall aphid, 1 per cent tar oil (Parrott, Hartzell, Glasgow & Harman 1931).

European red mite, no first generation mites on leaves following 2.4 per cent tar oil plus 3 per cent lubricating oil (Ginsburg & Driggers 1938).

Peach leaf curl, 96 per cent control with 4 per cent tar oil (Stanley, Marcovitch & Andes 1934).

Low Temperature Tar Oil.—In the spring of 1937 the senior author tested a

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tar oil that seemed less caustic than similar materials included in the experiments. This oil† had been distilled from tar recovered in the carbonization of soft coal at temperatures of 450–500 degrees C., upon eggs of the European red mite was negligible.

The comparative blandness of the low temperature product, and its effectiveness against aphid eggs, led to inquiry re-

Table 1.—Results of early season sprays on apple, 1937.

Item No.	Materials Per Cent Concentration or Amount Per 100 Gallons	Place	Aphids Per 100 Buds After Delayed Dormant	Per Cent Red Mite Hatch on Prepared Twigs	Per Cent Leaves Infested by First Brood Mites
	Dormant Sprays. Arendtsville, April 7; State College, April 12				
1	High temperature tar oil 2.4%, petroleum oil 3%	S.C.*	0.3	10.0	42.0
		A.†	0.6	14.5	12.0
2	*Dowspray Dormant* 2.25 gal.	S.C.	0.0	16.2	28.4
		A.	0.0	11.5	12.0
3	Dried tar oil 5 lbs., petroleum oil 3%	A.	0.0	14.5	22.0
4	Dried tar oil 8 lbs., petroleum oil 4%	A.	2.0	8.5	8.0
5	Low temperature tar oil 2.5% in soap emulsion	S.C.	0.0	44.5	92.6
	Delayed Dormant Sprays. Arendtsville, April 17; State College, April 19				
6	Petroleum oil 3%, liquid lime sulfur 2.5 gal.	S.C.	4.0	17.2	18.5
		A.	3.7	23.2	0.0
7	As item 6, plus nicotine sulfate 1 pint	S.C.	2.3	16.5	24.5
		A.	0.0	18.7	12.0
8	As item 6, plus pyrethrum extract *DX* 1 pint	S.C.	4.6	11.7	25.2
		A.	0.0	12.5	6.0
9	Liquid lime sulfur 12.5 gal., lead arsenate 3 lbs., 40% nicotine sulfate 1 pint	S.C.	0.6	63.0	86.2
		A.	0.0	32.2	64.0
10	As item 9, with nicotine sulfate replaced by *DX* 1 pint	S.C.	7.0	63.2	86.0
		A.	9.7	28.2	28.0
11	Check—no treatment	S.C.	196.0	74.0	91.5
		A.	52.5	61.7	62.0
	Least significant difference	*S.C.*	*11.2*	*4.6*	*13.1*
		A.	*9.6*	*10.2*	*14.8*

* At State College on young McIntosh.
† At Arendtsville on mature Wealthy.
Sources of materials: item 1, B. G. Pratt Co.; item 2, Dow Chemical Co.; items 3 and 4, Central Chemical Co.; item 5, Pittsburgh Coal Carbonization Co.; *DX* pyrethrum, B. G. Pratt Co.

whereas the tar oils in commercial use meet the specifications published by Hartzell, Harman & Reed (1935), and are distilled from tar produced when soft coal is heated to temperatures of 925–1,000 degrees C. in the manufacture of illuminating gas. As may be seen in table 1, this low temperature tar oil proved to be satisfactory against aphid eggs at 2.5 per cent strength, at which level its effect

† Supplied by the Pittsburgh Coal Carbonization Company, Oliver Building, Pittsburgh, Pa.

garding its composition in comparison with high temperature tar oils. A paper by A. C. Fieldner and associates (1932) in the U. S. Bureau of Mines yielded the information presented in figs. 1 to 3.

The composition of coal tar is affected by the source of the coal and the kind of retort used, as well as by the temperature of carbonization. The results illustrated in the figures were secured in a closed experimental retort, and the tar produced was doubtless somewhat different from

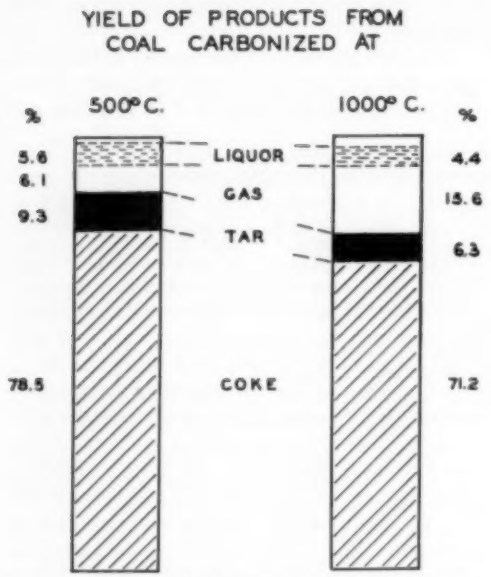

FIG. 1.—The principal products obtained from bituminous coal, as affected by the temperature of carbonization.

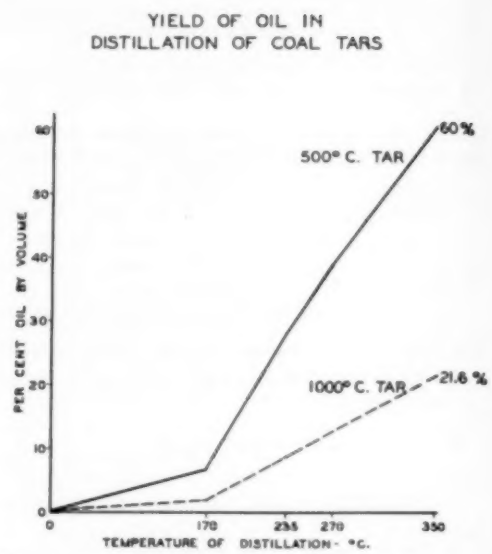

FIG. 2.—Graph showing the superior yield of oil from coal tar produced at low temperatures of carbonization.

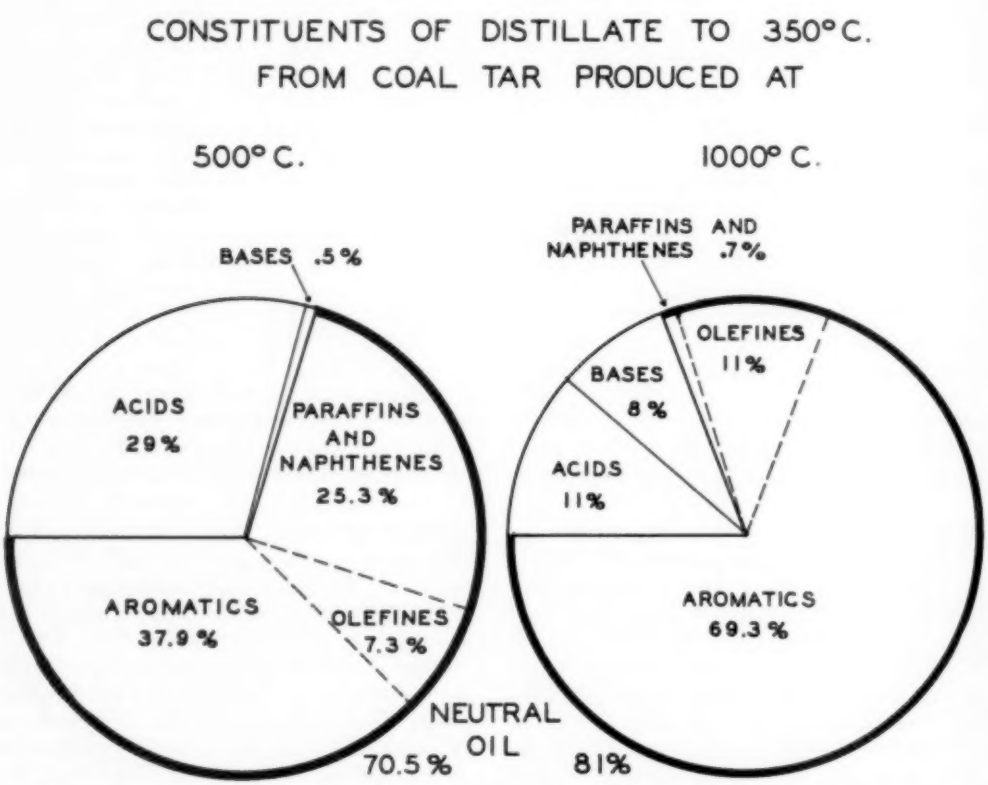

FIG. 3.—The composition of coal-tar distillates secured from tars produced in the carbonization of bituminous coal at low and high temperatures.

Table 2.—Some differences in coal tar distillates from different sources.

DISTILLATE COMING OFF TO	PER CENT DISTILLATE FROM TAR PRODUCED AT TEMPERATURE OF	
	450–500°C.	925–1,000°C.
210 degrees C.	0.0	Not more than 1
235 degrees C.	0.4	Not more than 10
270 degrees C.	8.6	—
315 degrees C.	37.8	—
355 degrees C.	68.7	Less than 65
Tar acids	34–40%	Not more than 10%, 5% preferred
Viscosity (Engler) —50 degrees C.	3.1	—
Specific gravity 38/15.5 degrees C.	1.057	—
Crystals after 3 hours at 5 degrees C.	none	To be removed

that yielding the distillate tested, for the latter was secured from partly oxidized coal in a rotating carbonizer where the semi-coked coal was the chief product. In general, however, the low temperature product tested differed from high temperature tar oils as indicated in the figures.

The most suggestive differences between low and high temperature tars are the relatively high percentage of tar acids (high boiling) and of paraffins and naphthenes in the former product. Although the distribution of tar acids, olefines, aromatics, paraffins and naphthenes in fractions distilled from low temperature tar is not revealed, the fraction used surely contained more paraffins and less aromatics than the high temperature tar oils.

Table 3.—Effect of early season sprays against European red mite eggs on prepared twigs. Arendtsville, Pa., 1938.

MATERIALS Per Cent Concentration or Amount Per 100 Gallons	RANK	NUMBER OF EGGS		PER CENT HATCH	PER CENT CONTROL
		Treated	Failing to Hatch		
Dormant Sprays					
Low temperature tar oil 2.4%, *Diamond Paraffin* oil 4%	1	1,734	1,477	14.8	82.9
DN-oil (98–2) 3%	2	1,413	1,189	15.8	81.7
Petroleum oil plus toxicant 2.5%	11	1,853	1,272	31.4	63.7
DN-oil (96–4) 2%	12	1,837	1,237	32.7	62.2
Pratt's "83" 4% oil, *Pratt's "Straitar"* 2.4% oil	15	1,875	824	43.9	49.2
Low temperature tar oil 4.5%	16	1,258	574	45.7	47.2
Elgetol 2%	17	1,585	510	67.8	21.6
Elgetol 0.75%	18	1,516	261	81.5	5.8
Elgetol 1%	19	1,526	263	82.8	4.3
Check	—	1,723	233	86.5	—
Green Tip Sprays					
Diamond Paraffin oil 3%, Bordeaux 2–6–100	4	1,625	1,286	20.9	76.4
DN-oil (98–2) 3%	5	1,676	1,297	22.6	74.5
Diamond Paraffin oil 3%, pyrethrum powder 2 lbs.	7	1,690	1,294	23.4	73.6
Diamond Paraffin oil 3%, nicotine sulfate 1 pt.	8	1,689	1,251	25.9	70.8
Diamond Paraffin oil 3%, liquid lime sulfur 2.5 gal.	10	1,339	928	30.8	65.3
Pratt's "83" 3% oil, liquid lime sulfur 2.5 gal.	13	1,281	838	34.6	61.0
Pratt's "83" 3% oil, cresylic acid 0.5%	14	1,438	820	43.1	51.4
Check	—	1,734	196	88.7	—
Delayed Dormant Sprays					
Diamond Paraffin oil 2%, Bordeaux 2–6–100, nicotine sulfate 1 pint	3	2,137	1,701	20.4	76.9
Diamond Paraffin oil 2%, liquid lime sulfur 2.5 gal.	6	2,255	1,737	23.0	74.0
Diamond Paraffin oil 2%, liquid lime sulfur 2.5 gal., nicotine sulfate 1 pt.	9	2,208	1,582	28.4	67.9
Liquid lime sulfur 12.5 gal., nicotine sulfate 1 pt.	20	2,296	292	87.3	1.3
Liquid lime sulfur 12.5 gal., pyrethrum powder 2 lbs.	21	2,409	292	87.9	0.7
Check	—	2,094	251	88.5	—

The material supplied was known as "heavy" oil, and was obtained by the redistillation of roofing pitch from which light oils and tar acid oils had already been driven off. Neither phenols nor cresols were present. A comparison of this oil with that specified by Hartzell & Reed (1935) is given in table 2.

With the thought that the high boiling board, eight twigs per board. The twigs on three boards were sprayed with each mixture used in the field before the spray rig entered the orchard. The boards were then placed in a screened insectary, and when hatching on the untreated twigs was complete, were scored for eggs remaining unhatched. The results of these treatments are given in table 3.

Table 4.—Field sprays against rosy aphid and European red mite. York Imperial, Blue Ribbon Orchard, Arendtsville, Pa., 1938.

Materials Per Cent Concentration or Amount Per 100 Gallons	Rosy Aphid Rosetted Spurs Per 1,000, June 10–11	Red Mite Infested Leaves Per 1,000, May 2–5	Notes on Spray Injury
Dormant Sprays, Applied March 25			
DN-oil (96–4) 2%	3	1.4	Buds retarded and burned
Low temperatore tar oil 2.4%, *Diamond Paraffin* oil 4%	1	9.6	Buds severely burned
DN-oil (98–2) 3%	2	14.4	Buds retarded and burned
Pratt's "83" 4% oil, *Pratt's "Straitar"* 2.4% oil	0	16.0	Buds normal
Low temperature tar oil 4.5%	1	35.2	Some buds burned
Least significant difference	*3.2*	*26.4*	
Petroleum oil plus toxicant 2.5%	35	6.0	Buds normal
Elgetol 1%	9	80.4	Buds normal
Green Tip Sprays, Applied April 2			
Diamond Paraffin oil 3%, liquid lime sulfur 2.5 gal.	67	23	Slight burning—buds retarded
Pratt's "83" 3% oil, liquid lime sulfur 2.5 gal.	26	27	Buds scorched
DN-oil (98–2) 3%	26	29	Severe burning
Diamond Paraffin oil 3%, Bordeaux 2–6–100	43	42	Buds normal
Pratt's "83" 3% oil, cresylic acid 0.5%	47	78	Buds scorched
Diamond Paraffin oil 3%, nicotine sulfate 1 pt.	95	38	Buds normal
Diamond Paraffin oil 3%, pyrethrum powder 2 lbs.	154	40	Buds normal
Delayed Dormant Sprays, Applied April 16			
Diamond Paraffin oil 2%, liquid lime sulfur 2.5 gal. nicotine sulfate 1 pt.	5	12.6	Severe burning
Diamond Paraffin oil 2%, liquid lime sulfur 2.5 gal.	34	16.0	Severe burning
Diamond Paraffin oil 2%, Bordeaux 2–6–100, nicotine sulfate 1 pt.	3	23.6	Buds normal
Liquid lime sulfur 12.5 gal., nicotine sulfate 1 pt., lead arsenate 3 lbs.	0	194.4	Severe burning
Liquid lime sulfur 12.5 gal., pyrethrum powder 2 lbs., lead arsenate 3 lbs.	6	225.8	Severe burning
Least significant difference	*11*	*71.0*	
Checks	155	403.0	

and apparently noncaustic tar acids in the low temperature tar oil might increase its insecticidal action, and that the high percentage of paraffins might assist in red mite control, arrangements were made for further tests in 1938.

Tests in 1938.—Information on the strictly ovicidal effects of the materials tested was secured by mounting prepared twigs bearing known numbers of European red mite eggs on pieces of hard

In the field, spraying was done with a power rig and single-nozzle spray gun at 550 pounds pressure, and the trees were sprayed from the inside out as well as from the outside in. Results against the rosy apple aphid were secured by scoring 100 fruit spurs outside and 100 inside the foliage wall of each count tree as infested or clean, on June 10 and 11. Results obtained against the European red mite were judged by examinations of the foli-

age in early May, when first generation mites were mature. Twenty fruit spurs per tree were selected at random, and the leaves were counted and recorded as infested or clean. These results are reported in table 4. The first five treatments listed under each spraying date were arranged in Latin squares of single tree plots. The remaining treatments were each applied to five neighboring trees in the same orchard.

MATERIALS.—Low temperature tar oil, as specified in table 3, was supplied by the Pittsburgh Coal Carbonization Company. Used with *Diamond Paraffin* oil, a lubricating oil of medium viscosity, the mixture was emulsified by being pumped over in the tank with 0.5 pound per 100 gallons of lignin pitch (*Goulac*). Used alone, it was supplied as a mayonnaise type emulsion containing 68 per cent tar oil, 1.6 per cent lignin pitch, 0.8 per cent kaolin and 29.6 per cent water.

The DN oils were supplied by the Dow Chemical Company. The one referred to as DN-oil (96-4) was *Dowspray Dormant*, and DN-oil (98-2) was an experimental product containing 98 per cent lubricating oil and 2 per cent dinitro-o-cyclohexylphenol.

The B. G. Pratt Company supplied two mayonnaise type emulsions, "*83*" an 83 per cent lubricating oil emulsion, and "*Straitar*" an 85 per cent emulsion of high temperature tar oil.

In most mixtures, *Diamond Paraffin* oil was emulsified in the tank with lignin pitch at 0.5 pound per 100 gallons of spray. The emulsifying agent was omitted, however, in the mixtures employing 2-6-100 Bordeaux mixture.

"Petroleum oil plus toxicant" refers to an experimental product of the Central Chemical Company, of composition unknown to the authors, later named *Nitrocide*.

Elgetol, a dinitro cresol derivative, was supplied by Standard Chemical Products, Inc.

The ground pyrethrum flowers used contained 0.84 per cent pyrethrins, according to John Powell and Company, the producers.

APHID CONTROL.—Rosy aphid attack was not severe in the experimental blocks, and only 15.5 per cent of the fruit spurs became rosetted on unsprayed trees. The results reported in table 4 agree in general with those of 1937, presented in table 1. Among the dormant treatments both high and low temperature tar oils were effective at 2.4 per cent concentration. *Dowspray Dormant* at $2\frac{1}{4}$ gallons per hundred was perfectly effective in 1937, and the DN oils (98-2) at 3 per cent and (96-4) at 2 per cent were highly effective in 1938. *Elgetol* at 1 per cent strength gave slightly poorer results, and the Central Chemical Company material was evidently used at too low a concentration.

Eggs of the rosy apple aphid were hatching from about March 24 to April 9. None of the "green tip" applications of April 2 approached the effectiveness of some dormant and delayed dormant sprays against this insect.

Among the delayed dormant treatments 2 per cent lubricating oil plus summer strength lime sulfur gave indifferent results except upon the addition of nicotine sulfate at 1 pint per 100 gallons. At this period, whether lubricating oil or winter strength liquid lime sulfur is used for scale control, the addition of nicotine sulfate seems necessary for aphid control. Pyrethrum powder at 2 pounds per 100 gallons gave results somewhat inferior to nicotine sulfate, as judged by the figures in the table. These must be accepted with caution, however, for injury to the buds from the use of winter strength liquid lime sulfur was so severe that aphids were in danger of starvation before new foliage appeared.

EUROPEAN RED MITE CONTROL.—The effects of early season spray treatments against this fruit pest are difficult to evaluate. Population density varies greatly from branch to branch and from tree to tree, and sampling must be extensive if counts of mites upon the foliage are to be accepted. In addition, treatments may have differential effects upon the natural enemies of mites. Garman (1938) reports the almost complete removal of predacious thrips from trees sprayed with tar oils, but not from trees sprayed with petroleum oils. Conversely, petroleum oils are detrimental to eggs of *Diaphnidia pellucida* Uhler, a mirid bug that in its younger stages feeds upon the European red mite (Steiner 1938). Tests of ovicidal action tell nothing of effects upon predators, and they have other drawbacks as well. In the present study the kill of eggs upon prepared twigs was

less in 1938 than in 1937, a result thought now to be due to a change in technique. In 1937 the twigs were suspended in the trees in more or less natural positions for spraying and drying, while in 1938 they were mounted vertically upon boards. A majority of the eggs are laid beneath twigs, in crotches and about the bases of spurs; places that usually receive the greatest deposits of spray material. The method of mounting twigs for laboratory tests in 1938 was not favorable to the collection of spray droplets at these points.

The results of the ovicidal treatments, as given in table 3, must be considered with the above limitations in mind. Even the leading treatments failed to exhibit the desired degree of control. However, comparisons among treatments are considered to be valid.

Among the dormant treatments low temperature tar oil used alone at 4.5 per cent concentration proved to possess low ovicidal efficiency, but at 2.4 per cent strength added to 4 per cent lubricating oil it appeared to depress the ovicidal action of the latter less than the high temperature tar oil. There is a possibility that this effect is more apparent than real, however, for the two types of tar oil were not emulsified equally well, and the low temperature material gave severe injury, which may well have interfered with the establishment of newly-hatched mites upon the foliage.

Some supplementary information on the low temperature tar oils has been supplied through the courtesy of W. C. Ferguson, Entomologist for the Pittsburgh Coal Carbonization Company. In laboratory tests employing the technique just discussed, low temperature tar oil was slightly superior in ovicidal effect to a commercial mixture (37–46) of high temperature tar oil and lubricating oil, at a total oil content of 6 per cent; and it retained its effectiveness to a greater degree upon reduction to 4.5 and 3.0 per cent total oil. A lighter fraction of low temperature tar oil was less effective. Removal of the high boiling tar acids from the heavy fraction resulted in the loss of about 75 per cent of its toxicity to eggs of the European red mite.

In the DN oils the added toxicant seemed to have little effect upon European red mite eggs, for a spray containing 1.92 per cent oil and 0.08 per cent DN was about half as effective as one containing 2.94 per cent oil and 0.06 per cent DN. Apparently dinitro-o-cyclohexylphenol does not fortify the oil for red mite control. Similarly, the unknown toxicant in the Central Chemical Company oil, and *Elgetol* at 2 per cent strength seemed relatively harmless to red mite eggs.

Among the remaining treatments *Diamond Paraffin* oil, at 3 per cent strength in the green tip and 2 per cent in the delayed dormant, gave best results when emulsified with 2-6-100 Bordeaux mixture. It will be noted that the addition of cresylic acid to the lubricating oil appeared to reduce the ovicidal action of the latter.

The results of the field sprays, as judged by the moderate numbers of mites upon the foliage near the end of the first generation, table 4, are not entirely consonant with the results of the ovicidal tests. For instance, DN-oil (96-4) appeared to be more effective than DN-oil (98-2), and *Diamond Paraffin* oil in the green tip and delayed dormant sprays appeared to give better results with lime sulfur and *Goulac* than with Bordeaux mixture. However, the good ovicidal properties of the dormant mixture of low temperature tar oil and lubricating oil are reflected in the foliage counts, as well as the low ovicidal effectiveness of the low temperature tar oil alone, the *Elgetol* and the delayed dormant applications of winter strength liquid lime sulfur.

INJURY TO APPLE BUDS.—In the 1937 tests no injury was observed, either at Arendtsville or at State College. In 1938, however, an unprecedented scorching and killing of buds occurred. The unseasonably warm weather prevalent in March forced the buds into a silver tip stage before the dormant sprays could be applied. This doubtless accounts for much of the injury from the dormant materials, and emphasizes anew the cautions in the use of these materials. In addition, it is suspected that the unusual warmth rendered the developing tissues more susceptible to injury from the green tip and delayed dormant treatments. Table 4 contains notes on the occurrence and severity of the injuries observed.

Among the dormant materials, the DN oils produced injury in every case, and the (96-4) combination at 3 per cent strength was thought for a time to have killed the

trees outright. Foliage counts in this treatment were impossible. Injury was slight where the prepared emulsion of low temperature tar oil was used. With the factory-mixed emulsions of lubricating oil and high temperature tar oil no injury occurred, but with the tank-mixed lubricating oil and low temperature tar oil an imperfect emulsion resulted, and severe injury was produced. *Elgetol* at 1 per cent strength did not injure the buds, nor did the Central Chemical Company material at 2.5 per cent concentration. However, neither is effective at these concentrations.

Among the delayed dormant sprays, the time-honored mixture of winter strength liquid lime sulfur, lead arsenate and nicotine sulfate burned the early leaves severely, as did summer strength lime sulfur with lubricating oil, in both the delayed dormant and green tip periods. The safening effect of Bordeaux mixtures with oil at both stages of development is evident.

SUMMARY.—High temperature coal tar creosote emulsions (tar produced at 925–1,000 degrees C.) are effective sprays for the control of several fruit tree and other pests, but they are caustic in nature, of questionable value against eggs of the European red mite and appear to depress the action of lubricating oils against the eggs of this species.

A low temperature coal tar creosote emulsion (tar produced at 450–500 degrees C.) differs from the high temperature material chiefly in its higher percentage of tar acids (of high boiling range) and of paraffins, and its lower percentage of aromatics. This material appears to be less caustic than the high temperature tar oils. It is as effective as the latter against aphid eggs, and in mixture with lubricating oil it seems to have less depressing effect on the toxicity of the petroleum oil to red mite eggs. It has not been tested against other insects subject to control by tar oils.

Really adequate control of the European red mite has not been demonstrated by any of the materials reported. However, the mixtures of low temperature tar oil and lubricating oil, and of lubricating oil with added toxicants, merit further study. However, dinitro-o-cyclohexylphenol and sodium dinitro-ortho-cresylate appear to be only slightly toxic to eggs of the European red mite. From the standpoint both of injury and effectiveness, lubricating oil emulsified with Bordeaux mixture should be tried further in the green tip and delayed dormant stages of tree development.

Difficulties in the evaluation of early season sprays against the European red mite are pointed out in this paper.—11-18-38.

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Experiments With Nicotine for the Control of Codling Moth*

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During the past 10 years a large amount of work has been done and extensive data accumulated in an effort to utilize and adapt nicotine for the control of codling moth on apples. The bulk of this work has dealt with the development of the so-called fixed nicotines and includes contributions from numerous workers in state experiment stations, federal bureaus and commercial concerns. Recently Hough (1938) published results which open up a new field and extend the possibilities for the use of nicotine in codling moth control. He found that nicotine or nicotine sulfate added to sprays of lead arsenate and summer oil, or fixed nicotine and summer oil, used against the first brood of codling moth improved the control to such an extent that no second brood sprays were necessary. The addition of a pint of nicotine to 100 gallons of these ovicidal and larvicidal sprays brought about this result by destroying approximately 75 per cent of the moths found in the tree at the time the spray was applied. Hough's data showed also that the addition of the nicotine killed a high percentage of eggs due to hatch within a day or two after the spray was applied.

Hough's work with this so-called triple spray treatment aimed at eradicating the first brood of codling moth represents a most significant and important advance in the development of a satisfactory control for codling moth. While these spray combinations are expensive, the indications are that if they are properly used the final expense of producing a clean crop of apples is no greater than the expense of usual treatments necessary to control first and second brood codling moth.

The present paper sets forth two seasons' results in the use of nicotine sulfate (*Black Leaf 40*) in combination with oil and lead arsenate, and with oil and fixed nicotine, under southern New Jersey conditions. In this area the codling moth has two and a partial third brood, resulting in worm activity extending from May until September. The tests were run in one of the large orchards near Glassboro where excessively heavy codling moth populations had been allowed to build up.

TRIPLE SPRAY TREATMENT IN 1937.—A large orchard made up mostly of 30-year old Winesap trees spaced 40 feet apart was selected for the tests in 1937. Approximately one-fourth of this acreage was divided into three plots, 9 by 14 trees each. Plot 1 was sprayed with lead arsenate, 3 pounds to 100 gallons of a 1–3–50 Bordeaux, in the first cover spray following the calyx spray; then lead arsenate, 3 pounds, plus oil, 3 quarts to 100 gallons, was used in the second, third and fourth cover sprays applied at intervals of 10 days. This plot represented the special lead arsenate plus summer oil treatment recommended for orchards in southern New Jersey heavily infested with codling moth and served as a check for the two triple spray plots. Plot 2 was sprayed the same as plot 1, except that 1 pint of nicotine sulfate to 100 gallons was added in each of the four cover sprays. Plot 3 was sprayed with lead arsenate, 3 pounds, plus nicotine sulfate, 1 pint to 100 gallons of a 1–3–50 Bordeaux, in the first cover spray, then bentonite, 2 pounds, nicotine sulfate, 1½ pints, plus summer oil, 3 quarts to 100 gallons of water, was used in the second, third and fourth cover sprays.

To determine the relative effectiveness

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of the three plot treatments several hundred apples were examined on the trees in each plot at the end of first brood worm activity. In addition, three trees with comparable crops were selected near the center of each plot and wormy apples dropping to the ground in June, July and August were collected and recorded. Observations made during and at the end of first brood activity indicated that first brood had not been sufficiently controlled in the triple spray plots to warrant omitting second brood spraying entirely. Therefore, additional second brood sprays of oil plus lead arsenate were applied on all three plots excepting the three marked trees in each plot.

TRIPLE SPRAY TREATMENT IN 1938.—The control of first brood with the triple spray treatment in 1937 was not so complete as anticipated, being much poorer than the results obtained by Hough in Virginia, even though four sprays were applied at intervals of 10 days and covered the activity of first brood completely. Observations made relative to the method of application seemed to offer a satisfactory explanation as to why poorer results were obtained. When the plots were sprayed in 1937, the grower's equipment and labor were used and the usual procedure was followed of spraying from the ground with single nozzle guns. In practice the spray rig is driven between the rows and two men spray, each taking one row. The procedure followed was for the operator to spray the underside of the tree first, directing the spray upward and outward, then to complete the job from the outside, spraying all around the tree. Observations made at the time the sprays were going on showed that many of the moths were disturbed and flew from the trees without coming in contact with the spray. Another weakness of this method of spraying, recognized by most investigators engaged in field tests for codling moth control, is the relatively poorer coverage of fruit and foliage in the tops of the trees, resulting in higher percentages of worm entry in that area, particularly on large trees.

It was thought advisable and worthwhile to repeat the experiments in 1938, using the same plots and essentially the same materials and schedules, but to modify the method of application so as to obtain a better kill of the adult moths. Although the senior writer had been following the Virginia experiments closely for several years by personal visits to the experimental plots in Virginia and otherwise, it was not realized until the 1937 tests were well under way that the method of application might prove important. In the Virginia tests two men applied the sprays. One stood on the ground and used a four nozzle rod, while the other used a six nozzle rod from a tower on top of the tank. Driving down one side of a row of trees and spraying two-thirds of each tree top and bottom from the outside served to trap the moths in the tree, thus leading to a higher kill as well as more uniform coverage.

For the 1938 tests a motorized 400-gallon, 18- to 20-gallon a minute capacity rig was equipped with a tower on the spray tank consisting of two 50-gallon oil drums mounted one on top of the other. One man using a six nozzle rod was stationed in the tower and another using a single nozzle gun walked behind. The rig was driven slowly down the rows of trees on the windward side, the operator in the tower spraying the upper two-thirds of the tree while the one on the ground took care of the lower third. On the return trip the opposite side of the row of trees was sprayed similarly.

Codling moth emergence and tree development in 1938 was unusually early in the Glassboro area. The four cover sprays were applied May 9, 20, 31 and June 10. Plot 1 was sprayed with lead arsenate, 3 pounds to 100 gallons of a 1–3–50 Bordeaux, in the first cover spray after the calyx spray followed at 10-day intervals by three cover sprays of lead arsenate, 3 pounds, lime, 2 pounds, oil, 3 quarts, spreader one-half pound to 100 gallons of water. Plot 2 was sprayed with the same materials as plot 1 plus one pint of nicotine sulfate to each 100 gallons of spray in all four cover sprays. Plot 3 was sprayed with *Black Leaf 155*, 8 pounds, *Coposil*, 2 pounds, nicotine sulfate, 1 pint to 100 gallons, in the first cover spray after the calyx spray. The second, third and fourth cover sprays on this plot consisted of *Black Leaf 155*, 4 pounds, oil, 3 quarts, plus nicotine sulfate, 1 pint to 100 gallons.

In addition to the three plots described above, which were sprayed essentially the same as in 1937 with the exception of the

Table 1.—First brood codling moth injury following four cover sprays using different spray materials.

Plot No.	Treatment	Per Cent Codling Moth Injury 1937	1938
1	Lead arsenate plus oil	30.0	40.9
2	Lead arsenate plus oil plus nicotine sulfate	10.0	11.0
3	Fixed nicotine plus oil plus nicotine sulfate	10.0	9.5
4	Lead arsenate plus oil	—	60.4

method of application, a fourth plot of Winesaps adjoining the tree plots already described and consisting of as many trees as the three plots combined was available for further observations. This large block of trees was sprayed the same as plot 1 (lead arsenate plus oil) with the same spray rig and crew except that all spraying was done from the ground with single nozzle guns similar to the procedure followed in the plot arrangement in 1937.

Five trees were selected in each of the four plots following the fourth cover spray on June 10. It was planned to apply no additional sprays on these marked trees and to make suitable examinations relative to codling moth injury on the trees at intervals during and at the end of the season. The remaining trees in each of the plots were to be sprayed or not as moth activity warranted following the fourth cover spray in June.

Tree Counts Compared to Drop Counts.—The writers examined 300 apples on each of the five trees at the end of June in each of the four plots to determine the extent of codling moth attack under the various treatments. A similar examination at the end of first brood activity was made on the three plots in 1937. The percentage codling moth injury by first brood in 1937 and 1938 is given in table 1.

The data in table 1 show a distinct improvement in codling moth control on plots 2 and 3 which received the triple spray treatment as compared to plots 1 and 4 which did not receive any nicotine for adult moth control. That the method is important is shown by a study of the 1937 and 1938 figures. In 1937 when all plots were sprayed from the ground there was three times as much stinging on the plot sprayed with lead arsenate plus oil as was present on the two plots receiving the triple spray. In 1938 the plot sprayed from the ground entirely with lead arsenate plus oil (plot 4) had from five to seven times as much injury as the two triple spray treatments. Plot 1, which received lead arsenate plus oil in 1938 but was sprayed from the outside from a tower, was definitely poorer in codling moth control than the triple spray plots 2 and 3 but superior to plot 4, which was sprayed from the ground entirely.

Another, and perhaps better, method of comparing the differences in codling moth control as a result of the various treatments and methods of application is to determine the number of wormy apples per tree. On late ripening varieties, such as Winesap, practically all wormy apples produced by first brood attack will drop to the ground shortly after the worms have matured. Taking advantage of this, the writers collected all wormy apples at weekly intervals, beginning in June and continuing to harvest on each of three trees in each plot in 1937 and on each of five trees in each plot in 1938. The data in table 2 show the number of wormy apples per tree collected from each plot in June and July. Since the bulk of the wormy apples produced by first brood attack drop during this period, the figures indicate the relative effectiveness of the different spray treatments in controlling first brood adults, eggs and larvae.

The data in table 2 show even more clearly than the data in table 1 the effectiveness of a pint of nicotine sulfate added to a spray of lead arsenate plus oil

Table 2.—Number of wormy apples resulting from first brood codling moth attack on different spray treatments at Glassboro.

Plot No.	Treatment	Wormy Apples Per Tree* 1937	1938
1	Lead arsenate plus oil	174	86
2	Lead arsenate plus oil plus nicotine sulfate	13	9
3	Fixed nicotine plus oil nicotine sulfate	49	16
4	Lead arsenate plus oil	—	272

* Average of three trees per plot in 1937 and five trees per plot in 1938.

or fixed nicotine plus oil. The 1937 results show 174 wormy apples per tree produced by first brood on the lead arsenate plus oil as compared to 13 per tree on the lead arsenate plus oil plus nicotine sulfate and 49 per tree on the half charge bentonite nicotine plus oil plus nicotine sulfate. The superiority of lead arsenate plus oil plus nicotine sulfate over fixed nicotine plus oil plus nicotine sulfate agrees with the results reported by Hough (1938). It should be pointed out, however, that only a half charge of 2 pounds of bentonite plus one-half pint of nicotine was used as the larvicide on plot 3 in 1937. Furthermore, the first fixed nicotine spray followed a spray of lead arsenate plus Bordeaux, and Steiner & Sazama (1938) have shown that under these conditions the effectiveness of the fixed nicotine is reduced by the carbonate residue remaining from the spray preceding the fixed nicotine spray.

Turning to the 1938 figures in table 2, we find that the triple spray of lead arsenate plus oil plus nicotine sulfate slightly superior to the triple spray of *Black Leaf 155* plus oil plus nicotine sulfate. Both triple sprays proved many times superior to the two lead arsenate plus oil sprays. That the method of application is important is brought out by the figures in table 2 for plots 1 and 4. Plot 4, which was sprayed from the ground entirely, had three times as many wormy apples as plot 1, sprayed from the tower.

COMPARATIVE CONTROL FOR THE SEASON.—The drops from the marked trees in each plot in the 1937 and 1938 test were collected weekly from June to harvest in September, when all the fruit was picked and scored for codling moth injury. The data in table 3 show the percentage codling moth injury of the combined drops and picked fruit for the different spray treatments in 1937 and 1938.

The data in table 3 show that the effect of the triple spray treatment, evident in the data taken at the end of first brood (tables 1 and 2), carried through to harvest. In 1937 the final harvest figures showed 88.3 per cent worms and 98.3 per cent total codling moth injury on the lead arsenate plus oil (plot 1). The lead arsenate plus oil plus nicotine sulfate (plot 2) showed 12.3 per cent worms and 68.4 per cent total injury. The half charge of fixed nicotine plus oil plus nicotine sulfate (plot 3) was better than plot 1 but inferior to plot 2 with 40.4 per cent worms and 88.7 per cent total injury.

Table 3.—Percentage codling moth injury on plots sprayed for first brood control only.

PLOT NO.	TREATMENT	PER CENT CODLING MOTH INJURY			
		Wormy		Total	
		1937	1938	1937	1938
1	Lead arsenate plus oil	88.3	45.0	98.3	76.5
2	Lead arsenate plus oil plus nicotine sulfate	12.3	34.0	68.4	65.7
3	Fixed nicotine plus oil plus nicotine sufate	40.4	34.0	88.7	46.7
4	Lead arsenate plus oil	—	71.6	—	97.4

The data in table 3 for 1938 show 45 per cent worms at harvest and 76.5 per cent total injury for lead arsenate plus oil sprayed from the tower as compared to 71.6 per cent worms and 97.4 per cent total injury for lead arsenate plus oil sprayed from the ground. The two triple spray plots 2 and 3 both showed 34 per cent wormy with the former 65.7 per cent total injury and the latter 46.7 per cent total injury at harvest.

DISCUSSION.—A casual examination of the data in table 3 would lead one to conclude that while the triple spray treatment showed some improvement over the double spray treatment, the results are considerably removed from even a commercial control of codling moth. However, in interpreting and evaluating data from field plots in codling moth investigations it is necessary not only to apply the sprays and take records at harvest time but to consider other factors. Steiner & Sazama (1938) have pointed out one such factor, namely, moth movement. It will be recalled that the trees from which the data in table 3 were taken received the last of

four first brood cover sprays on June 10. Up to June 20 very little worm injury was evident in plots 2 and 3, which had received the triple spray treatment. From June 25–30 fresh attempts at entry were observed in plots 2 and 3. Observations showed that this fresh activity was more pronounced on plots 2 and 3 where they joined plot 4 and became progressively less toward the middle and opposite ends of these two plots. At the same time fresh entry was prevalent in plots 1 and 4 which had not received nicotine for the adult moths. It was evident that moths were drifting into plots 2 and 3 from plot 4, each plot where both the first and second brood sprays were applied was examined and scored for codling moth injury. The results, set forth in table 4, represent picked fruit and drops at harvest but do not represent drops picked up throughout the season.

The data in table 4 show that the three additional sprays, one on first brood and two on second brood, brought through to harvest 60 per cent of the crop on the trees free of codling moth injury on the triple spray plots 2 and 3. Plot 1, sprayed both broods with lead arsenate plus oil from the tower, showed 31.4 per cent

Table 4.—Results of triple spray treatments for first brood followed by three additional sprays for first and second brood.

Plot No.	Treatment	Percentage of Apples		
		Clean	Stung	Wormy
1	Lead arsenate plus oil	31.4	54.5	14.1
2	Lead arsenate plus oil plus nicotine sulfate	60.0	35.9	4.1
3	*Black Leaf 155* plus oil plus nicotine sulfate	61.8	28.8	9.4
4	Lead arsenate plus oil	6.0	57.1	36.9

which was on the side of the prevailing winds. The result of these observations was the decision to spray all the plots with a fifth cover spray for first brood on June 30. Plots 1 and 4 were sprayed with lead arsenate plus oil and plots 2 and 3 were sprayed with oil plus nicotine. This spray was omitted on the five marked trees in each plot.

First and Second Brood Treatments.—Subsequent observations at the end of first brood activity indicated that enough larvae had escaped the first brood sprays, particularly in plots 1 and 4, to warrant spraying all of the plots for second brood. Consequently two additional sprays of oil plus lead arsenate were applied on plots 1 and 4. Plots 2 and 3, with the exception of the marked trees already referred to, received two second brood sprays of nicotine sulfate plus oil plus lead arsenate on plot 2 and nicotine sulfate plus oil plus *Black Leaf 155* on plot 3.

At harvest all the fruit on three trees in clean whereas plot 4, sprayed with the same materials but from the ground, showed only 6 per cent clean.

Summary.—Two years' tests with a triple spray of nicotine sulfate, oil and lead arsenate or fixed nicotine, aimed at reducing first brood of codling moth to such a low point that little or no second brood spraying will be necessary, shows that the addition of a pint of nicotine sulfate (*Black Leaf 40*) to 100 gallons of a spray mixture containing an ovicide and larvicide definitely improves the control. Lead arsenate proved more effective as the larvicide than fixed nicotine. Spraying from the outside of the tree using multiple nozzle rods as opposed to spraying from the ground with single nozzle guns tended to trap the adult moths in the trees, thus increasing the adult moth kill and resulting in better control. Observations indicated that the full effects of the triple spray treatments were not obtained because moths drifted in from adjoining blocks of trees.—11-18-38.

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Pyrethrum and Derris as a Control for the Six-Spotted Leafhopper, a Vector of Lettuce Yellows*

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The virus disease known as lettuce yellows has become a serious limiting factor in the production of fall lettuce in New Jersey. The spring crop is not seriously damaged by the disease. According to Kunkel (1926) and Severin (1929, 1932) this virus is identical with that which causes yellows in aster, celery, carrot, parsley and many other wild host plants. The disease is known under several local common names. According to Severin (1929) it is known as "white-heart" or "rabbit-ear" in New York and as "Rio Grande disease" in Texas. The New Jersey lettuce growers refer to the disease as "crazy lettuce," "wild lettuce" and "lettuce rosette." All types of lettuce in New Jersey are subject to infection by the virus. Fig. 1 shows a healthy and a diseased Romaine lettuce plant, and figs. 2 and 3 show a healthy and a diseased Boston lettuce plant. Severin (1929) reports that the disease is of little economic importance in California. Caesar & Ross (1933) report lettuce yellows in Ontario, but apparently the infection was light.

FIG. 1.—Romaine lettuce. Left, yellows infested plant; right, healthy plant.

The yellows virus is transmitted by the six-spotted leafhopper, *Macrosteles divisus* (Uhl.), (formerly known as *Cicadula sexnotata* (Fall). There has been some confusion regarding this species of leafhopper, but Dorst (1937) has revised the group and evidently the species is now properly named. *M. divisus* has a very wide range of host plants, including vegetable and truck crops, cereal and forage

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crops, flowers and weeds. Considerable damage by this leafhopper has been reported on oats, corn, timothy and pasture grasses by Osborn (1912). It has been observed that large populations of the aster

FIG. 2.—Big Boston lettuce, yellows infested plant.

leafhopper occur on vegetable crops in New Jersey but the amount of direct damage caused by the species is not known.

CONTROL MEASURES.—Since many of our vegetable farmers were cutting their acreages in lettuce due to lettuce yellows it was necessary to start an investigation on ways to overcome the heavy losses in the lettuce crop or else New Jersey would have to go out of fall lettuce production. In 1936 a series of experiments were started in an effort to reduce the loss from the virus diseases to a point where it would still be profitable to grow fall lettuce.

Three ways of attacking the problem have been followed, namely, fencing or caging, insecticidal control and roguing.

FENCING, 1936–1937. — Since aster growers had resorted to caging their aster plantings to protect them from the leafhopper attack it was decided to set up an experiment on fencing and caging lettuce to find out if by elimination of the leafhopper the disease could be controlled and to determine the practicability of the method as a commercial control. In 1936, 25 Romaine lettuce plants were protected by individual cylindrical screen wire cages. None of these plants showed symptoms of the disease.

A cheesecloth fence 50 feet long, 25 feet wide and 6 feet high—with no top—was constructed in a Romaine lettuce planting before the plants came up. A storm destroyed this fence when the Romaine was about half grown. Records were taken at harvest, however, and 6 per cent of the plants in the fenced plot were diseased while 28 per cent of the unfenced plants were diseased.

In 1937 the same experiment was repeated, a reinforced tobacco cloth fence 7 feet high being used. This plot was 100 feet long and 50 feet wide, and Iceberg lettuce was used in place of Romaine. This fence stood during the season, but a small number of leafhoppers were able to fly over the fence and feed on the enclosed lettuce. At harvest 1 per cent of the fenced lettuce was diseased while 31.8 per cent of the check plants were diseased.

Although the disease may be almost completely eliminated by fencing it is impossible to use this method of control on the average lettuce farm because (1) the cost of fencing is too great, and (2) irrigation of the crop is almost impossible under this condition.

INSECTICIDES, 1936–1937.—In 1936 and 1937 small plot experiments were laid out in triplicate, each plot being approximately one-twenty-fifth of an acre in size. Applications of the various materials

FIG. 3.—Big Boston lettuce, healthy plant.

were made at 10-day intervals for a total of five applications.

In 1936 seven combinations of various materials were tested. The tests were (1)

rotenone-pyrethrum-sulfur, (2) copper plus lime dust (25–75), (3) derris marc plus sulfur, (4) derris root plus talc plus sulfur ($\frac{3}{4}$ per cent rotenone), (5) nicotine sulfate (1–600) plus soap, (6) nicotine sulfate (1–600) plus *Aresket*, (7) Bordeaux mixture 3–5–50 and (8) check. The results were that the rotenone-pyrethrum-sulfur and derris root plus sulfur dusts gave a significant reduction in the leafhopper nymph population and a slight decrease in diseased plants while the other combinations gave practically no control of either leafhopper or the disease.

In 1937 eight dust combinations were tested on small 3-replicate plots. These dusts consisted of pyrethrum, pyrethrum-sulfur, derris root plus sulfur, derris root plus pyrethrum plus sulfur, pyrethrum plus varying amounts of activator, pyrethrum plus neutral copper and pyrethrum plus one per cent *Santomerse*. The activator used is known as *D.H.S. Activator* and was furnished by Hercules Powder Company.

The pyrethrin content of the pyrethrum dusts was 0.3 per cent, the rotenone content of the derris root was 0.75 per cent and the pyrethrin-rotenone contents of the derris root plus pyrethrum plus sulfur dust were reduced to one-half the normal strength. No sulfur was present in the dusts containing *D.H.S. Activator*. When sulfur was used the content was always 25 per cent.

All dusts in 1937 were applied at 10-day intervals, starting when the plants were approximately 10 days old. Each plot was dusted five times.

Aster leafhopper nymph population records were taken at various intervals during the season and at harvest, while the disease records were taken only at harvest. The pyrethrum dusts containing sulfur, the derris root plus sulfur and derris root plus pyrethrum plus sulfur dusts gave best control of leafhopper and the disease while pyrethrum plus *D.H.S. Activator* gave a good control of leafhopper, but failed to give any appreciable reduction in diseased plants. Neutral copper added to pyrethrum did not increase the efficiency of the dust. The efficiency of all dusts in reducing the percentage diseased plants was low in all cases.

It was the opinion of the writers that the reason for the low reduction in diseased plants in the treated plots was that migration of leafhoppers from plot to plot took place throughout the season. It was also believed that if larger plots had been used migration might have been overcome to some extent, consequently reducing the percentage of diseased plants in the treated plots. The 1938 experiments bear out these points.

ROGUING, 1937.—A roguing experiment was conducted in 1937, wherein one-half of a 2-acre field of Romaine lettuce was rogued weekly, beginning as soon as the first symptom of the disease appeared and continuing until harvest. The check plot contained 12.9 per cent diseased plants at harvest while only 4.4 per cent of the plants in the rogued plot were removed due to disease.

INSECTICIDES, 1938.—Since it was felt that the small plot system used in 1936 and 1937 allowed so much migration of leafhoppers from plot to plot that some of the insecticides failed to give control, it was decided to use larger plots in 1938. The 1938 experiments will be classed as small plot experiments and large plot experiments. For the small plot experiments two fields of Romaine lettuce of about one-half acre each were divided into four plots each, thus giving one-eighth acre to each plot. One plot in each field was left as a check. The large plot experiments consisted of one-half acre fields of Romaine lettuce, wherein a small part of each of the fields was left as a check. The remainder of each field was treated with one material.

All materials were applied with a continuous action, rotary type, hand duster, using approximately 25 pounds of dust per acre per application. Treatments of the various plots were made at seven-day intervals starting when the first leaves were about one-half inch in diameter and the plants were about 10 days old. The number of leafhoppers present on the young lettuce when the treatments were started was exceedingly small.

The treatments on the small plots are set forth in table 1. This table gives the detailed information on the dust mixtures employed.

LEAFHOPPER POPULATION RECORDS, 1938.—Only the nymphal stage of the leafhopper was taken into consideration in these experiments because the adults migrate too freely and although adults

Table 1.—Insecticidal treatments to control the aster leafhopper on Romaine lettuce.

Plot No.	Treatment
	Field No. 1
1.	Pyrethrum (0.8%) 50 lbs., sulfur 25 lbs., talc 25 lbs.
2.	Derris root (4% rotenone+16% total extractives) 18¾ lbs., sulfur 25 lbs., talc 56¼ lbs.
3.	*Stemtox A* (0.5% pyrethrins) 80 lbs., sulfur 20 lbs.
4.	Check—no treatment.
	Field No. 2
5.	*Stemtox D* (0.05% pyrethrins) 75 lbs., sulfur 25 lbs.
6.	Derris root (4% rotenone) 12½ lbs., *Stemtox D* 25 lbs., sulfur 25 lbs., talc 37½ lbs.
7.	Check—no treatment

may have been present in the treated plots we have no proof that they were actually feeding on the plants.

The sweeping method was used in taking samples. Each sweep was made by holding a standard insect net (14 inch diameter) at arm's length and, forming an arc of 180 degrees, allowing the rim of the net to contact the tops of the plants. Nymph populations were taken on August 9, 23 and September 6. The first two population records were taken prior to dusting, while the last population record was taken just before harvest. These records are set forth in table 2.

Dust applications were made on July 26, August 2, 9, 16, 23 and 30.

The two fields, designated as such in table 2, were treated as individual experiments because there was a significant difference in the populations in the two check plots. This difference may be accounted for by the fact that field no. 2 bordered on a cucumber field where there was a rank growth of vegetation and it was observed that large leafhopper population was present in the cucumber field before the Romaine germinated.

The lettuce yellows records from these same plots are set forth in table 3.

Table 2.—Aster leafhopper nymph population on various treated plots of Romaine lettuce.

Plot No.*	Number Sweeps	Population				Per Cent Reduction in Population
		8/9	8/23	9/6	Average	
			Field No. 1			
1	10	2	5	1	2.7	96.8
2	10	3	4	4	3.7	95.6
3	10	5	8	7	6.7	92.1
4	10	67	81	103	83.7	—
			Field No. 2			
5	10	51	58	47	52.0	45.9
6	10	23	37	30	30.0	68.8
7	10	76	94	118	96.0	—

* For treatments see table 1.

Table 3.—Lettuce yellows records from the various treated plots of Romaine.

Plot No.*	Number Diseased Plants/100 Sample Numbers					Total	Per Cent Diseased	Per Cent Reduction in Diseased Plants
	1	2	3	4	5			
				Field No. 1				
1	20	13	13	14	15	76	15.2	74.5
2	14	16	17	16	12	75	15.0	74.9
3	13	17	19	16	19	84	16.8	71.9
4	62	54	59	57	66	298	59.8	—
				Field No. 2				
5	41	49	52	40	49	231	46.2	40.9
6	26	18	25	24	15	108	21.6	72.4
7	69	79	77	84	82	391	78.2	—

* See table 1 for plot treatments.

There is a definite correlation between the nymph population and the percentage of diseased plants in the various plots. The per cent reduction in diseased plants is not so great as the per cent reduction in the nymph population. This may be due to migration of the leafhoppers. The adult leafhoppers are probably also a factor in spreading the virus.

Plot no. 6, which received derris root (½ per cent rotenone) plus *Stemtox D* plus sulfur had a rather large leafhopper population. The per cent reduction in diseased plants was almost as great as in any of the other treatments.

Since each field was approximately 60 feet wide by 350 feet long, a 50-foot strip on one end of each field was left as a check. The treatment of each field is given in table 4.

The disease records from the above plots are set forth in tables 5.

Table 4.—Treatments of large lettuce plots for the control of aster leafhopper and lettuce yellows.

Field No.	Treatment*	Nymph Population/10 Sweeps				Per Cent Reduction in Nymph Population
		8/23	9/6	9/20	Average	
1	Pyrethrum flowers (0.8%) 50 lbs., sulfur 25 lbs., talc 25 lbs.	0	5	4	3.0	97.3
1A	Check	82	99	143	108.0	—
2	*Stemtox A* (0.5% pyrethrins) 80 lbs., sulfur 20 lbs.	7	5	5	5.7	94.5
2A	Check	64	108	137	103.0	—
3	Derris root (4% rotenone) 18⅔ lbs., sulfur 25 lbs., talc 56¼ lbs.	2	4	2	2.7	97.8
3A	Check	77	121	162	120.0	—

* Application dates: August 9, 16, 23, 30, September 6 and 13. Field No. 3 was planted to Iceberg while all others were Romaine. Treatments were started when the first leaves were approximately ½ inch in diameter.

In comparing the data on the various fields it should be kept in mind that these fields must be treated as individual experiments due to the variation which might have occurred between the fields, in leafhopper migration from adjoining host plants, the proximity of diseased plants, etc. These large plots do, however,

Table 5.—Lettuce yellows records from large plot experiments.

Plot No.*	Number Diseased Plants/100 Plant Sample					Total	Per Cent Diseased	Per Cent Reduction in Disease
	1	2	3	4	5			
1	7	9	8	10	8	42	8.4	89.1
1A	78	73	81	77	73	382	76.4	—
2	12	9	14	10	10	55	11.0	85.8
2A	80	76	71	78	82	387	77.4	—
3	6	5	4	4	7	26	5.2	88.8
3A	41	48	46	46	50	231	46.2	—

* See table 4 for treatments.

LARGE PLOT EXPERIMENTS, 1938.—After the small experimental plots were under way it was decided to test some of the materials on larger plots. Two fields of Romaine lettuce and one field of Iceberg of about the same planting date were available for the experiments. Each of the three fields was more or less isolated; in them individual check plots would have to be established for each treated field. show that the diseased plants can be greatly reduced by the treatments. In comparing the data in table 5 with those in table 3 it is to be noted that the larger plots run lower in per cent diseased plants although the leafhopper populations run approximately the same as exhibited in tables 2 and 4.

All dust mixtures contained 20 per cent to 25 per cent sulfur, and it is interesting

to note that the *Stemtox A* dust contained only 20 per cent sulfur while the other mixtures contained 25 per cent. In every case the *Stemtox A* plots ran slightly lower in both leafhopper and disease control. Data collected in 1936 and 1937 show the same trend, that is, materials containing the same quantity of active insecticide but varying amounts of sulfur showed results favoring the larger quantity of sulfur.

To further substantiate results from these experimental plots the writers had the occasion to visit a lettuce farm at Pinebrook, N. J., where commercial applications of derris-sulfur were applied. The dust used here was a commercial brand containing 0.75 per cent of rotenone and 25 per cent sulfur. Applications were made at weekly intervals, starting when the first leaves were approximately one-half inch in diameter. All plantings of lettuce ran less than 10 per cent of diseased plants whereas in previous years some plantings were a total loss and all plantings contained 40 per cent or more of the disease. Lettuce plantings on neighboring farms showed from 40 per cent to 75 per cent loss due to the disease.

Table 6.—Roguing as a control for lettuce yellows.

Date Rogued	Number Plants Removed
August 30	343
September 6	142
September 13	68
September 20	115
September 27	16

Total diseased plants 684.
Total plants 6,030
Per cent diseased plants 11.2
Per cent diseased plants in check 23.0

ROGUING EXPERIMENT, 1938.—Since roguing proved to be fairly effective in 1937 it was decided to test this method of yellows control on a large plot again in 1938.

A planting of Romaine 50 feet wide by 400 feet long was divided into two plots of 50 feet by 200 feet. One of the plots was rogued once a week and all plants showing symptoms of yellows were removed from the field. The data from this experiment are set forth in table 6.

The field was examined on August 23 and no diseased plants were in evidence, but the largest number of plants removed at a single time was seven days later. It is believed that if these early diseased plants had been rogued at a shorter interval, a better control might have been obtained through roguing.

SUMMARY.—Lettuce yellows disease is a serious limiting factor in the production of fall lettuce in New Jersey. The virus is transmitted by the six-spotted leafhopper, *Macrosteles divisus* (Uhl.). Fencing to protect lettuce from leafhopper attack was successful in 1937, in that only 1 per cent of the protected lettuce showed symptoms of the disease, while the loss in the check plots was 31.8 per cent.

Small plot experiments with insecticides in 1936 and 1937 showed that a very high degree of leafhopper control was possible while the decrease in the disease was very slight. This was thought to be due to migration of the adult leafhopper.

In large plot experiments conducted in 1938 rotenone and pyrethrum dusts gave good control of the leafhopper, which in turn reduced the amount of the virus to the extent that a commercial crop of lettuce was harvested.

Roguing, although not so effective as insecticides, has given approximately 50 per cent reduction in lettuce yellows.—11-18-38.

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Stomach Poisons and the Two-Striped Grasshopper; Special Reference to Arsenic and Fluorine Compounds*

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During the summer of 1936, four species of grasshoppers were abundant in Iowa. Of these, *Melanoplus f. femur-rubrum* (DeG.) and *Melanoplus differentialis* (Thos.) had previously been the subject of stomach poison tests (Richardson & Haas 1932; Richardson & Thurber 1933); another species, *Melanoplus m. mexicanus* (Saus.), was present in destructive numbers, although it was somewhat more abundant the following year when it was employed to survey the toxic behavior in bran-water baits of a rather large number of chemical compounds and mixtures (Richardson & Seiferle 1938). The fourth species, the two-striped grasshopper, *Melanoplus bivittatus* (Say), was widely distributed in the state, but was most numerous and destructive in the southern and western counties. Since this grasshopper had not previously been used in individual feeding experiments with poison baits, it was selected as the test insect for an investigation, detailed below, which extended from June 23 to August 5, 1936.

MATERIALS.—Eight chemical compounds were used in this investigation. These were chemically pure arsenic trioxide; sodium arsenite, as NaH_2AsO_3, prepared from chemically pure arsenic trioxide and sodium hydroxide; chemically pure sodium fluoride and sodium fluosilicate; commercial barium fluosilicate; cryolite, a commercial grade known as *Alorco*, which contained 84.3 per cent Na_3AlF_6; commercial chloroacetamide; and pure phenothiazine ($C_{12}H_9NS$).

In addition to water, the food ingredients of the baits consisted of clean, flaky wheat bran and dark cane molasses.

Only adult insects were used in the tests. They were captured in the field and kept in large outdoor cages supplied with fresh corn foliage. The individuals employed in the tests were unselected for size, but an effort was made to keep the numbers of the sexes approximately equal.

METHODS.—The food ingredients of the baits, bran, molasses and water, were mixed in the following proportion by weight respectively, 25:6:34. The poison was added in amounts to furnish baits with various, predetermined concentrations of toxic substance.

The bait was administered by allowing the insect, previously weighed, to feed from a portion of the mixture in a paraffined paper container. The container with its contents was weighed quickly on a Roller-Smith precision balance before and after feeding. The feeding was done in a moist chamber in which the moisture content of the bait remained constant within the limits of error of the method. Dosage was regulated partly by adjusting the concentration of the poison in the bait, as described above, and partly by interruption of the insect during feeding. After feeding, the grasshopper was transferred to a small wire screen cage where it was fed fresh corn foliage daily, and observed several times each day until death, or if apparently unaffected, for a period of five days.

The criterion of death was the inability of the insect to move when the tarsi or palpi were pinched with forceps.

Controls were maintained throughout the period of experimentation, there being about two controls to three experimental insects. In 389 control insects observed from June 26 to July 27, the natural mortality was 21.3 per cent; in 117 controls observed from July 28 to August 5, the mortality was considerably greater, namely 52.1 per cent.

RESULTS.—The experimental data were analyzed statistically, so far as possible, by relating percentage mortality with dosage, the latter being the quantity of poison consumed in milligrams per gram of body weight of the insect. For arsenic trioxide, sodium arsenite, sodium fluosilicate and sodium fluoride, the data were sufficient to permit analyses by the method of Bliss (1935). This was done by arraying the doses and grouping them into dosage ranges whose means corresponded with the mean percentages of mortality for the respective dosage ranges. These crude mortality values were con-

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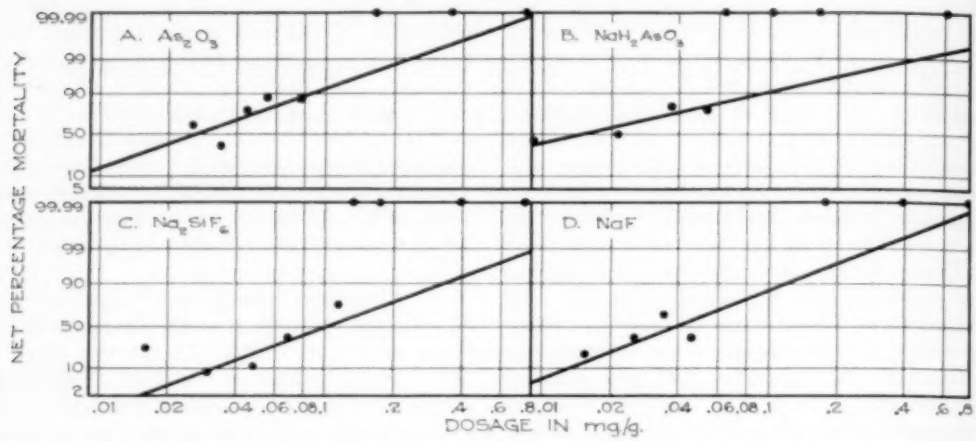

FIG. 1.—Logarithmic-probability graphs expressing dosage-mortality relationships of four compounds to *Melanoplus bivittatus*. The curves are fitted to the observed data by a least mean square method (Bliss 1935). The As_2O_3 curve (*A*) is based upon data from 186 insects, NaH_2AsO_3 (*B*) from 131, Na_2SiF_6 (*C*) from 240 and NaF (*D*) from 81 insects. Because of the small number of insects used, the NaF curve is less precise than the others.

verted to net mean percentage mortalities by correcting them for the natural mortality in the controls. The results are expressed by graphs, fig. 1. The graph for sodium fluoride is fitted to inadequate data, and the median lethal dose obtained from it must be considered provisional.

The data for the remaining four compounds were not sufficiently extensive for analysis and determination of the median lethal dosage. They are brought together in fig. 2.

Fig. 3 expresses the relationship be-

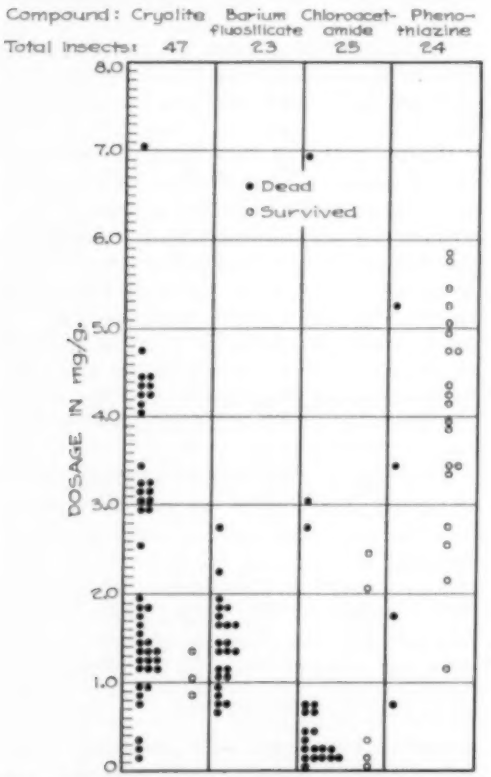

FIG. 2.—Chart showing death and survival of *Melanoplus bivittatus* after specific doses of cryolite, barium fluosilicate, chloroacetamide and phenothiazine.

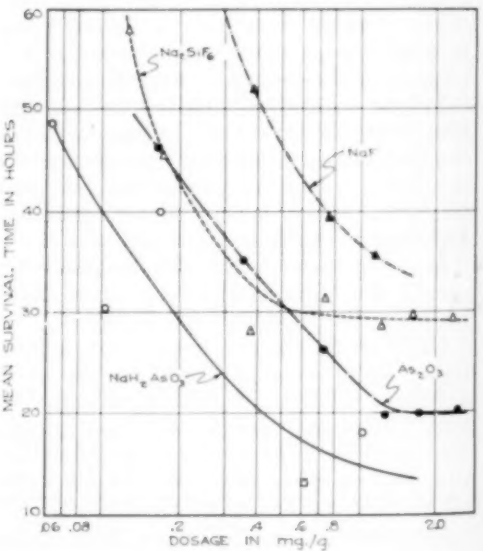

FIG. 3.—Curves showing the effect of dosage of four compounds on the survival times of *Melanoplus bivittatus*. Survival times are estimates; curves are fitted by eye to the experimental data.

tween dosage and survival time for the compounds in fig. 1.

DISCUSSION.—The four compounds which are the chief concern of this article have now been tested on several species of grasshoppers. The median lethal doses are given in table 1.

Table 1.—Median lethal doses in milligrams per gram of body weight.

COMPOUND	*Melanoplus birittatus*	*Melanoplus f. femur-rubrum**	*Melanoplus differentialis***
Arsenic trioxide	0.026	(0.36)†	0.09
Sodium arsenite (NaH_2AsO_3)	0.015	0.10	—
Sodium fluosilicate	0.100	0.12	—
Sodium fluoride	(0.040)†	—	0.11

* Richardson and Glover 1932.
** Richardson and Thurber 1933.
† Values are provisional.

There is considerable difference in the susceptibility of these grasshoppers to the four poisons. Particularly, *Melanoplus birittatus* seems to be more susceptible than the other species to the arsenical poisons. Of these compounds sodium arsenite is considerably the more toxic, especially when the comparison is made on the basis of the As_2O_3 equivalence of NaH_2AsO_3, the median lethal dose then being 0.0095 milligram per gram. A well-marked difference seems also to exist between the median lethal doses of these two arsenical compounds for *M. f. femur-rubrum*. On the other hand, the median lethal doses of sodium fluosilicate for *M. birittatus* and *M. f. femur-rubrum* are similar.

Of the four compounds in fig. 2, cryolite was lethal over a dosage range of about 0.2 to 4.8 milligrams per gram; no recoveries were obtained after doses greater than 1.4 milligrams per gram. It is possibly more toxic than sodium fluosilicate to this insect. Barium fluosilicate killed all the insects at doses from about 0.6 to 2.8 milligrams per gram. No recoveries occurred in this range. Chloroacetamide was lethal from less than 0.1 to about 3.0 milligrams per gram, but there were a few recoveries at dosages up to 2.4 milligrams per gram. It was impossible to feed larger doses of chloroacetamide as the compound appeared to be rather repellent. Phenothiazine was apparently nontoxic at doses as high as 5.8 milligrams per gram. The few deaths that occurred may be considered the result of normal mortality in the population.

In fig. 3, the dosages for arsenic trioxide, sodium arsenite, sodium fluosilicate and sodium fluoride are plotted against mean survival times in hours of the insects which died in five days or less. While the values for mean survival time are of only approximate accuracy, since observations on length of life after feeding were not continuous, nevertheless they furnish an estimate of the speed of action of these compounds. At 0.4 milligram per gram of sodium arsenite, survival was about 20 hours; the same dosage of arsenic trioxide and sodium fluosilicate permitted survival to about 33 hours, whereas 0.4 milligram per gram of sodium fluoride permitted survival to more than 50 hours. At higher doses, however, arsenic trioxide and sodium fluosilicate are differentiated, the survival time being about 20 hours for the former compound and just under 30 hours for the latter. The curves for all the compounds tend to flatten at high dosage; that is to say, survival time tends to become independent of dosage.

SUMMARY.—Eight chemical compounds were tested in the laboratory as stomach poisons in bran-water-molasses baits against adults of the two-striped grasshopper, *Melanoplus birittatus* (Say). Dosage was accomplished by an individual feeding method. The median lethal dose for arsenic trioxide was 0.026 milligram per gram of body weight, for sodium arsenite as NaH_2AsO_3, 0.015 milligram per gram and as As_2O_3, 0.0095 milligram per gram; for sodium fluosilicate 0.10 milligram per gram and for sodium fluoride 0.04 milligram per gram, the latter being an approximation. The susceptibility of two other species of grasshoppers to these poisons is discussed. Cryolite (sodium fluoaluminate) and barium fluosilicate in bran baits were apparently rather toxic to this insect, but the data were not sufficient to determine the median lethal doses. Chloroacetamide was lethal at relatively low doses but appeared to be rather repellent. On the other hand, phenothiazine was nontoxic at doses as high as 5.8 milligrams per gram. Sodium arsenite gave the shortest survival time, sodium fluoride the longest, while sodium fluo-

silicate and arsenic trioxide occupied an intermediate position.

ACKNOWLEDGMENT.—The writers of this paper wish to acknowledge the efficient and faithful assistance of Miss Lois L. Ames.—7-9-38.

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Studies of Rice Stinkbug Populations With Special Reference to Local Migration

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The rice stinkbug, *Solubea pugnax* (F.), is a common insect in rice fields in Louisiana, Texas and Arkansas each year and is one of the most important insect pests of this crop. Rice kernels injured by the stinkbug are known to the rice trade as "pecky rice." Spots varying in color from a light yellow with a sort of bleached appearance to coal black appear on the kernels following stinkbug punctures. These spots vary in shape and size. The most common shape is a circular spot about 2 millimeters in diameter, but spots range from the size of a pin point to one so large that it totally discolors the kernel. Research in cooperation with rice pathologists has indicated that some of this pecky rice is caused by disease organisms and that the size of the discolored spot may be increased by certain organisms entering the damaged kernel.

LOSSES FROM PECKY RICE.—The extent of losses from pecky rice has been calculated from figures obtained by the Federal-State grading offices* in Louisiana, Texas and Arkansas and by the American Rice Growers Association in Texas. In the system of grading rice used by the Bureau of Agricultural Economics, one of the items considered is total damaged kernels. Practically 99 per cent of all total damaged kernels are pecky. Price deductions for pecky rice are made as the grade quality decreases with the increase in the amount that is pecky. Losses from pecky rice in Louisiana, Texas and Arkansas are estimated as follows: 1930, $649,610; 1931, $352,191; 1932, $493,177; 1933, $644,974; 1934, $203,774; 1935, $365,064; and 1936, $629,346; or an estimated average annual loss of $476,877 for the seven-year period.

In addition to pecky rice, there is a loss due to the stinkbug which might be termed sterility. The rice listed as sterile is that which failed to produce millable kernels. The term is not strictly correct because some kernels show evidence of fertilization although the bugs sucked out the juices during the early milk stage of development so that only a more or less empty seed coat developed.

HIBERNATION.—The rice stinkbug spends the winter in the adult stage. It hibernates in grass and trash in and around the rice fields. Stinkbugs may be found in bunches of grass, near the surface of the soil, at any time during the winter months and are active when disturbed. J. W. Ingram (1927) has reported finding as many as seven in one clump of grass. The bugs come out of hibernation in April and begin feeding on a large variety of grasses. The generations overlap to some extent, but it is certain that two or three generations develop on these wild host plants before the bugs enter the rice fields.

HOST PLANTS.—Stinkbugs have been observed feeding on the following grasses which are common in and around rice

* The author is indebted to W. D. Smith, Supervisor in charge of Federal Rice Supervision and Federal-State Inspection Service, Bureau of Agricultural Economics, and to John Coffey of the American Rice Growers Association for their kindness and cooperation in making their records available for compilation of these data.

fields: *Panicum dichotomiflorum* Michx., *Panicum fasciculatum* Swartz. (possibly other species of *Panicum*), *Digitaria sanguinalis* (L.) Scop., *Echinocholoa colonum* (L.) Link., *Paspalum urvillei* Stued., *Paspalum longipilum* Nash, (possibly other species of *Paspalum*), and *Cynodon dactylon* (L.) Pers. This is not a complete list of wild host plants. *Paspalum urvillei* grows very abundantly in Louisiana and parts of Texas and is undoubtedly the most important of the grasses for stinkbug breeding. This species thrives well on rice fields levees, fence rows and sodland, and along highways. This insect has not been found feeding on any cultivated crop except rice.

MIGRATION AND FEEDING HABITS.—The main purpose of this paper is to give some information on the movement of these bugs to and from the rice fields. The most widely grown variety of rice ordinarily heads about August 15–20. As soon as the panicles emerge, millions of stinkbugs forsake the grasses and enter the rice fields, the adults by flight and the nymphs by crawling or swimming. There are a number of factors which influence

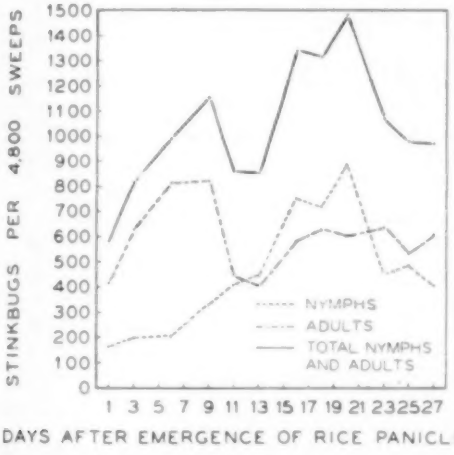

FIG. 1.—Stinkbugs collected at regular intervals in six fields, 1936. The graph shows maximum population period.

the movements of these insects. The adults are active fliers and will take wing at the least disturbance. When a field of early rice is cut, the population in an adjoining late-maturing field may increase by several thousands within a 24-hour period. Mowing the grass along the highway ditches also causes a sudden rise in the population in adjoining rice fields. The average maximum population for Louisiana fields is 2,430 bugs per acre. The maximum population recorded in any one field is 18,446 per acre. This was in a field near Katy, Tex., in 1937.

Counts over a period of years show that

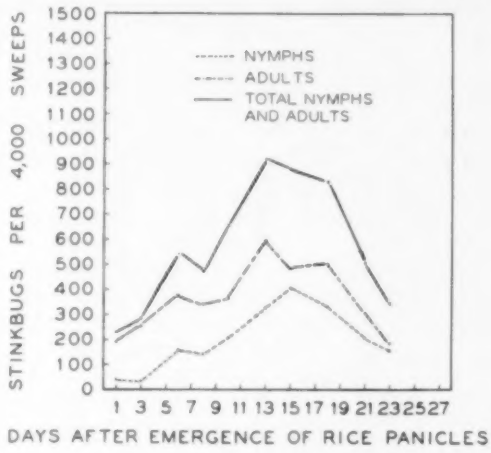

FIG. 2.—Stinkbugs collected at regular intervals in six fields, 1937. The graph shows maximum population period. A heavy rain (1.03 inches) fell on August 25. This was the only heavy rain that fell during the period of these sweeps, August 18–September 8. It corresponds with the drop in numbers of stinkbugs on the eighth day, and it is possible that the rain and wind knocked the stinkbugs off the plants or interfered with their feeding.

the average population is about 750 bugs per acre in rice fields during the period of from one to three days after the panicles emerge. The adults oviposit on the rice leaves, stems or panicles, and the nymphs begin feeding when they are two days old. The stinkbug population builds up at the rate of approximately 1,000 per acre per week until the rice kernels become too hard for feeding. All stages of the insect may be found at all times during the development of the kernels. Feeding occurs while the glumes and grains are green and succulent so that the bugs can penetrate and suck the juices from the developing kernels. These become too hard to be attractive to the feeding bugs within 8 to 10 days after fertilization. Maximum populations usually do not develop until a few days after the time when the rice is in optimum condition for feeding, because this time is past before some of the nymphs developing from eggs laid within

the fields reach the feeding stage. One complete and three partial generations develop in the rice fields by the time the rice is harvested.

The graphs shown in figs. 1 and 2 for sweepings made n 1936 and 1937 show the movement of the stinkbugs into rice fields, the rise in population due to immigration of adults and hatching of nymphs, and their reduction in numbers due to migration back to the grasses and levees which are the most common locations for hibernation.

Rain and wind tend to hinder feeding by knocking the nymphs off the panicles, and the adults seem to go down among the leaves for shelter. The nymphs are very active swimmers, and when knocked into the water they immediately swim to the nearest stem and crawl up to the panicle. Any time that danger seems to threaten a nymph, it simply loosens its hold on the plant, falls into the water and swims to another plant. The nymphs swim with a quick jerky movement similar to that of a frog. The stinkbugs are frequently found resting on the stems during cool windy days that occur occasionally in August and September. It was thought that possibly the stinkbugs feed at certain times of the day, so observations were made to determine if this is so. Table 1 gives a summary of these observations.

Table 1.—Stinkbugs found feeding in a rice field at various times of the day. Each number listed is the total of 200 sweeps of an insect net in the location. Stinkbugs found were recorded by individual sweeps.

Date	Number of Bugs								
	Hour 8–9 A.M.			1–30–2–30 P.M.			4–30–5–30 P.M.		
	Levee	Edge	Center	Levee	Edge	Center	Levee	Edge	Center
8-19-35	54	19	23	23	12	49	24	18	34
8-20-35	34	10	24	16	18	18	11	8	26
8-21-35	10	5	18	11	6	3	10	10	10
8-22-35	16	3	28	26	5	15	8	11	6
8-23-35	19	5	6	16	1	9	12	3	11
8-26-35	30	12	30	34	10	40	27	11	19
8-27-35	11	10	15	23	8	20	24	6	14
8-28-35	21	7	10	25	4	16	23	10	13
8-29-35	—	—	—	—	—	—	Rain		—
9- 2-35	41	13	21	29	4	16	14	13	20
9- 3-35	14	7	44	19	8	24	7	7	8
9- 4-35	23	19	24	34	13	23	18	17	19
9- 5-35	7	7	17	13	22	29	19	12	14
9- 6-35	Rain		—	—	—	—	—	—	—
9- 9-35	Rain		—	—	—	—	—	—	—
9-10-35	Rain		—	—	—	—	—	—	—
9-11-35	36	23	29	31	23	15	34	28	18
9-12-35	20	20	12	23	18	14	23	27	11
9-13-35	23	4	5	32	10	16	13	8	11
9-16-35	28	9	9	19	9	7	28	12	6
9-17-35	8	6	9	16	11	9	23	8	6
Totals	395	479	324	390	182	323	318	209	246

The data obtained in this field, which was swept three times per day during the development of the kernels, were analyzed statistically with the following results.

Variance due to	D/F	Sums of squares	Mean squares	F		
				Observed	For odds of 19:1	For odds of 99:1
Days	16	4,529.00	283.062	5.39	1.83	2.33
Times per day	2	199.47	99.735	1.95	3.07	4.78
Locations	2	2,826.92	1,413.460	26.91	3.07	4.78
Times × Locations	4	286.61	71.652	1.36	2.44	3.47
Error	128	6,722.99	52.523	—	—	—
Total	152	14,564.99				

Table 1 indicates the following:

1. A highly significant difference in the number of bugs caught per day.

2. No significant difference in the number of bugs feeding at different times of the day (8:00 A.M.–5:30 P.M.).

3. A highly significant difference in the number of bugs caught in different locations.

4. No significant difference in the number of bugs caught in the respective locations at different times of the day.

INFLUENCE OF PROXIMITY OF WILD HOST GRASSES.—It seemed probable at the beginning of this work that the number of stinkbugs in a field might be in direct proportion to the abundance of wild host plants growing on levees within the field and especially on the levees around the field, but this was not found to be the case under Texas conditions.

Populations per acre were roughly estimated in 26 fields from the number of bugs in 400 sweeps, covering about one-twelfth of an acre, in each. Nine of these fields contained wild host plants on the levees within and around them, and 17 fields did not. The average number of bugs per acre in the fields containing wild host plants was 3,465 for edge of field, and 3,133 for center of field, while the average number per acre in fields without wild host plants was 1,585 for edge of field and 2,448 for center of field. The fact that stinkbugs were abundant in fields in or near which no wild host plants were growing indicates that the adults fly considerable distances. The higher averages for the fields containing wild host plants are due to the extremely high population occurring in one of those fields. When this was omitted from the data, the average numbers of bugs per acre were slightly higher in the fields without wild host plants than they were in those containing wild host plants.—8-1-38.

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Egg Parasites of the Cotton Flea Hopper

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During June, 1936, while conducting life-history experiments with the cotton flea hopper, *Psallus seriatus* (Reut.), the junior author noticed that very few nymphs emerged from certain collections of host plants known to contain large numbers of flea hopper eggs. Upon investigation of the reason for this low emergence of flea hoppers, it was discovered that many mymarids were emerging in the cages. This confirmed the suspicion that the flea hopper eggs were being parasitized, and efforts were made to isolate eggs suspected of containing parasites. Fifty-seven such eggs were carefully removed from stems of *Croton* plants and placed in individual cages, and 57 parasites emerged. So far as known, no parasites had previously been recorded from this important cotton insect. Three of the parasites were identified by A. B. Gahan as *Anaphes anomocerus* Girault, a previously reported egg parasite of the garden flea hopper, *Halticus citri* (Ashm.), on alfalfa in Utah. The other 54 were determined as a new species which Gahan described as *Erythmelus psallidis* Gahan (Gahan 1937).

Studies were made of the distribution, abundance and life history of these parasites; and to determine whether any mirids other than the flea hopper were parasitized by these mymarids.

DISTRIBUTION AND ABUNDANCE.—Collections of croton, the preferred host of the cotton flea hopper for oviposition, were obtained from six states and caged at Port Lavaca, Tex., for emergence records. Ten average size *Croton* plants, or their equivalent in volume, were used as a basis for a caged collection. *Erythmelus psallidis* emerged from plants collected in Arizona, Arkansas, Louisiana, Mississippi, South Carolina and the 46 counties of Texas from which plants were collected. *Anaphes anomocerus* Girault was found

only from Arizona and 15 counties of Texas. Of the 41,947 flea hopper eggs in the stems of various plants collected in six states during 1936 and 1937, 30.2 per cent were parasitized. The parasitization of 11,337 eggs studied in 1936 was 25.6 per cent and of 30,610 eggs in 1937 was 31.9 per cent.

Erythmelus psallidis emerged from eggs in the following plants: Cotton, cowpea, *Chamaecrista robusta*, *Croton argyranthemus*, *C. capitatus*, *C. glandulosus*, *C. monanthogynus*, *C. texensis*, *Grindelia inuloides*, *Helenium tenuifolium*, *Monarda dispersa*, *Physalis viscosa*, *Solanum elaeagnifolium*, *S. rostratum*, and *Tidestromia lanuginosa*. *Anaphes anomocerus* Girault emerged from eggs in cotton, *Croton capitatus*, *C. monanthogynus*, *C. texensis*, *Helenium tenuifolium*, *Monarda dispersa*, and *Solanum elaeagnifolium*. It was more abundant than *E. psallidis* on horsemint, *Monarda dispersa*, in the spring and on bitterweed, *Helenium tenuifolium*, in the fall, but in all other cases *E. psallidis* greatly predominated or was the only parasite present.

LIFE HISTORY.—*Erythmelus psallidis* and *Anaphes anomocerus* each develop singly in a host egg. A limited number of records show that mating of *E. psallidis* takes place soon after emergence, one pair copulating within four hours after emerging as adults.

Out of a total of 71 *Erythmelus psallidis* that emerged on July 31, 1936, 35 were males and 36 females, indicating that the sexes are about equally divided. Several cotton flea hopper eggs known to be free from parasites were exposed to *E. psallidis* on August 10, 1937. Two parasites emerged from these eggs in 10 and 12 days respectively. Out of the thousands of *E. psallidis* that emerged during midseason from eggs in field collected plants, most of the emergence took place by the twelfth day, although there were a few parasites that required from 13 to 18 days. These records show that most individuals of this species develop from egg to adult in about 12 days. The majority of the emergence was early in the mornings, before 9:30 A.M. Several *Orius* sp. were observed feeding on *E. psallidis* adults in the vials of the emergence cages.

Efforts were made to determine how the parasites spend the winter. Much time was spent in February and March, 1937, in trying to isolate overwintering flea hopper eggs that were parasitized. Records were also made of the emergence from several hundred caged plants containing overwintering flea hopper eggs. Two specimens of *Erythmelus psallidis* were reared from isolated overwintering eggs, and 113 others emerged in the spring from eggs in plants that grew the previous season.

The overwintering condition of *Anaphes anomocerus* has not been definitely determined. Large numbers of adults were collected on several different plants early in March, 1938, indicating that possibly this species overwinters in the adult stage.

OTHER MIRIDS PARASITIZED.—Sensitive pea, *Chamaecrista robusta*, is a preferred host of the rapid plant bug, *Adelphocoris rapidus* (Say). *Erythmelus psallidis* did not emerge from collections of this plant except from those containing eggs of the cotton flea hopper. The same is true of cowpeas containing eggs of *Creontiades debilis* Van D.

Observations were made on a number of plants of *Croton capitatus* and *Parthenium hysterophorus* growing in close proximity to one another. The *Croton* contained many flea hopper eggs and the *Parthenium* contained many eggs of *Reuteroscopus ornatus* (Reut.). *Erythmelus psallidis* had equal opportunity of parasitizing the eggs of both of these mirids. Several collections of each of these plants were caged and a thousand or more eggs of *R. ornatus* hatched without a single individual of *E. psallidis* emerging, whereas many of these parasites, as well as many cotton flea hopper nymphs, emerged from the croton collections.

Studies in the spring of 1937 indicated that *Erythmelus psallidis* did parasitize eggs of *Reuteroscopus sulphureus* (Reut.). Forty-two of these parasites emerged from a collection of 100 plants of composite, probably *Grindelia inuloides*. No flea hopper nymphs hatched from this collection, and of the 25 mirid nymphs that emerged, 7 were reared to adults and identified as *R. sulphureus*.

One of *Erythmelus psallidis* emerged from a collection of *Physalis viscosa* plants. *Macrolophus separatus* (Uhler)* was very abundant on this plant, indicat-

* Identified by Dr. H. G. Johnston.

ing that this mirid is probably also a host of this parasite. These observations show a definite preference of *E. psallidis* for cotton flea hopper eggs.—7-28-38.

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Insect Pests of Derris

R. C. ROARK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The demand for insecticides that are relatively nontoxic to man has greatly stimulated the production of derris root. In 1938 the United States imported 742,661 pounds of crude derris root from British Malaya, the Dutch East Indies and the Philippine Islands. In addition, 590,854 pounds of crude lonchocarpus root and 1,735,995 pounds of powdered lonchocarpus root were imported, mostly from Brazil. Lonchocarpus root, commonly called barbasco, cubé or timbo, contains rotenone and most of the other insecticidal constituents of derris, and is practically equivalent to it for the control of many agricultural pests such as cabbage worms, the Mexican bean beetle and the pea aphid.

Many insects are recorded as attacking growing derris or stored derris root. It seems worth while to compile a list of these pests for the information of growers, shippers and importers of derris root and manufacturers and users of insecticides made from it. On account of the close botanical and chemical relationships of derris and lonchocarpus, it is probable that pests attacking one will also attack the other. Ths list should therefore be of interest to all persons having to do with rotenone-bearing plants.

Infestation of derris roots with insects has been observed in England (Cahn 1935), Holland (Spoon & Rowaan 1933), and the United States. The United States Department of Agriculture, Bureau of Entomology and Plant Quarantine (1936) reported that during the fiscal year 1935 a cargo of derris from the Dutch East Indies shipped to New York was found to contain *Sinoxylon conigerum* Gerst., and later (1937) it reported finding 53 larvae, 7 pupae and 43 adults, all living, of *S. anale* Lesne at New York on May 25 in derris roots in cargo from the Philippines.

Cahn (1935) wrote as follows concerning pests of derris:

> In large experience, however, incidence of insect attack is casual and not of a regularly recurrent nature. Thus, crops which had been permitted to become overgrown with weeds suffered from leaf-eating insects which were attacking the weeds. On the crop being clean weeded, however, no further damage occurred. In the same way, root harvested and baled and shipped home within a reasonable period, has never suffered by beetle infestation, but it has been found that root which has been stored in godowns and rubber smoke houses in Malaya, mostly for periods of one or two years, has become badly infested with root-boring beetles.

The Federated Malay States Department of Agriculture has called attention to these pests in many publications beginning with its annual report for 1924.

According to Grist (1935), beetles and larvae in stored derris roots may be destroyed by exposing the infested roots to bright sunlight for about five hours or fumigating with carbon disulfide at the rate of 2 to 3 pounds per 1,000 cubic feet for 72 hours.

According to Miller (1934c), the adult beetles will attack the root a few days after harvest, but it is more attractive to them when the moisture content is low. Infestation can be prevented by grinding the root and packing the powder in sealed tins or by packing the chopped root (2 inches long) in plywood chests of the kind used for the export of tea or rubber. A chest measuring 19 by 19 by 24 inches will hold about 100 pounds of dried root. Insects in roots can be destroyed by heating the roots, without scorching, for three days in a smokehouse. These beetles do not attack the roots of growing derris. The major pests are *Sinoxylon anale* Lesne, *Xylopsocus capucinus* (F.) and *Dinoderus minutus* (F.) (Miller 1934a).

Alphabetical List of Insects Attacking Derris

(Presumably *Derris elliptica* unless otherwise stated)

INSECT	FEEDS ON	REFERENCE
Alphitobius laevigatus (F.) [sic]	Roots in storage	Federated Malay States 1934a; Miller 1934a
Amsacta lactinea (Cram.) = (*Creatonotus lactineus* Cram.)	Leaves	Gater 1925a, b, c
Anisodes obliviaria Walk.	Leaves	Federated Malay States 1935
Anisodes obrinaria (Guen.)	Leaves	Gater 1925b, c
Apoderus corporaali Voss.	Leaves	Federated Malay States 1935
Arbela tetraonis Moore	*Deguelia microphylla* Valet	Roepke 1916
Aserica sp., probably *Autoserica*	Leaves	Federated Malay States 1935
Aspidolopha bifasciata (Ill.)	Leaves	Federated Malay States 1935
Belippa laleana (Moore)	Leaves	Gater 1925b, c
Borers	Roots in storage	Gater 1925b; Cahn 1935
Bostrichids (2 species)	Roots in storage	Gater 1925c
Bothrideres (?) *andrewesi* Grouv.	Roots in storage	Corbett 1931
Caterpillars (undetermined)	Branches (by boring into them)	Federated Malay States 1935
Chactadoretus borneensis (Kraatz)	Leaves	Federated Malay States 1935
Chrysomelids (3 species)	Leaves	Philippine Sugar Association 1934
A coccid	Twigs of *Deguelia microphylla* Valet	Girault 1917
Corigetus sp.	Leaves	Federated Malay States 1935
Craniotectus corbetti Laboiss.	Leaves	Corbett 1930; Federated Malay States 1934b, 1935; Grist 1935; Miller 1930, 1934b
(*Creatonotus lactineus* Cram.) = *Amsacta lactinea* (Cram.)	Leaves	Gater 1925a
Dinoderus bifoveolatus Woll.	Roots in storage	Corbett 1931; Federated Malay States 1934a; Miller 1934a; Muesebeck 1937
Dinoderus minutus (F.)	Roots in storage	Miller 1934a; Federated Malay States 1933b, 1934a
Epipsylla (near *albolineata* Kuwayama)	Leaves	Philippine Sugar Association 1934
(*Estigmene lactinea* Cram.) = *Amsacta lactinea* (Cram.)	Leaves	Gater 1925c
Eucosma balanoptycha Meyr.	Leaves and flowers	Federated Malay States, 1929; Gater, 1925b, c
Eucosma conciliata Meyr.	Leaves	Federated Malay States 1929
Eucosma defensa Meyr.	Leaves	Gater 1925b, c
(*Hasora alexis* F.) = *Hasora chromus* (Cram.)	Leaves	Federated Malay States 1924, 1935; Gater 1925b, c
Hasora simplicissima mixta (Mab.)	Leaves (?)	Wilkinson, 1928
Hedylepta indicata (F.) = (*Lamprosema indicata* F.)	Leaves	U. S. Dept. Ag., P.R. Exp. Sta. 1936
Homona coffearia (Nietn.)	Leaves	Federated Malay States 1929
Hypothenemus eruditus Westw.	Roots in storage	Corbett 1931; Federated Malay States 1934a; Miller, 1934a
Kalotermes tectonae D.	*Derris polyphylla* Benth.	Kalshoven 1930
(*Lamprosema diemenalis* Guen.) = *Nacoleia diemenalis* (Guen.)	Leaves	Gater 1925b, c
(*Lamprosema indicata* F.) = *Hedylepta indicata* (F.)	Leaves	U. S. Dept. Ag., P. R. Exp. Sta. 1936
Mahasena corbetti Tams.	Leaves	Federated Malay States, 1935
Mahasena sp.	Leaves	Federated Malay States, 1924; Gater, 1925c
Maruca amboinalis (Feld.)	Leaves	Gater 1925b, c
Maruca testulalis (Hbn.)	Leaves and flowers	Gater 1925c; Federated Malay States 1929, 1930, 1935
Minthea rugicollis (Walk.)	Roots in storage	Corbett 1931; Federated Malay States 1934a; Miller 1934a
Mocis undata (F.) = (*Remigia undata* F.)	Leaves	Federated Malay States 1929
Monophlebid scale insect	*Deguelia microphylla* Valet	Midden-Java Proefstation 1915
Nacoleia diemenalis (Guen.) = (*Lamprosema diemenalis* Guen.)	Leaves	Gater 1925b, c
Nisotra sp.	Leaves (?)	Federated Malay States 1930

INSECT	FEEDS ON	REFERENCE
(*Notolophus turbata* Butl.) = *Orgyia turbata* (Butl.)	Leaves	Federated Malay States 1935
(*Parata alexis* F.) = *Hasora chromus* (Cram.)		
Perissus laetus Lameere	Roots in storage	Federated Malay States 1934a; Miller 1934a
Phytoscaphus triangularis (Oliv.)	Leaves	Federated Malay States 1935
Proteides mercurius pedro (Dewitz)	Leaves	U. S. Dept. Ag. P. R. Exp. Sta. 1936
Pterolophia melanura Pasc.	Roots in storage	Miller 1934a; Federated Malay States 1934a
Ptinus fur (L.)	Roots in storage	Muesebeck 1937
Red spider		Cahn 1935
(*Remigia undata* F.) = *Mocis undata* (F.)	Leaves	Federated Malay States 1929
A scolytid	Roots in storage	Gater 1925c
Sinoxylon anale Lesne	Roots in storage	Federated Malay States 1926, 1931, 1932, 1933a, b, 1934a; Corbett 1931; Miller 1934a; Muesebeck 1937; Sakai 1934; Spoon & Rowaan 1933; U. S. Dept. Ag., Bur. Ent. and Plant Quar. 1937
Sinoxylon conigerum Gerst.	Roots in storage	U. S. Dept. Ag. Bur. Ent. and Plant Quar. 1936
Sinoxylon malaccanum Lesne	Roots in storage	Corbett 1931; Federated Malay States 1931, 1934a; Miller 1934a
Sinoxylon rugicauda Lesne	Roots in storage	Federated Malay States 1934a; Miller 1934a
Sinoxylon sp.	Roots in storage	Cahn 1935
Spodoptera pecten Guen.	Leaves	Federated Malay States 1935
Striglina scitaria (Walk.)	Leaves	Gater 1925b, c
A tenebrionid	Roots in storage	Gater 1925c
Tetranychus bioculatus W.-M.	*Derris robusta* Benth.	Andrews 1928
Xyleborus fornicatus Eichh.	*Derris robusta* Benth. in the field	Ceylon Tea Research Institute 1928; Holland 1931; Light 1928
Xylopsocus capucinus (F.)	Roots in storage	Corbett 1931; Federated Malay States 1933b, 1934a; Miller 1934a
Xylothrips flavipes (Ill.)	Roots in storage	Federated Malay States 1934a; Miller 1934a

The small chrysomelid beetle *Craniotectus corbetti* Laboiss.* is very destructive to growing derris. Only the adults cause damage by eating the leaves. A mixture of pyrethrum powder, petroleum, fish-oil soap and water killed 95 per cent of the beetles sprayed with it (Miller 1930).

The assistance of specialists in the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, in correcting the names and classification of the insects mentioned herein is gratefully acknowledged.

Classified List of Insects Attacking Derris

ISOPTERA

Termitidae: *Kalotermes tectonae* D.

HOMOPTERA

Psyllidae: *Epipsylla*, near *albolineata* Kuwayama
Coccidae:
- Monophlebid scale insect
- A coccid

COLEOPTERA

Bostrichidae:
- Bostrichids (2 species)
- *Dinoderus bifoveolatus* Woll.
- *Dinoderus minutus* (F.)
- *Sinoxylon anale* Lesne
- *Sinoxylon conigerum* Gerst.
- *Sinoxylon malaccanum* Lesne
- *Sinoxylon rugicauda* Lesne
- *Sinoxylon* sp.
- *Xylopsocus capucinus* (F.)
- *Xylothrips flavipes* (Ill.)

Cerambycidae:
- *Perissus laetus* Lameere
- *Pterolophia melanura* Pasc.

Chrysomelidae:
- *Aspidolopha bifasciata* (Ill.)
- Chrysomelids (3 species)
- *Craniotectus corbetti* Laboiss.
- *Nisotra* sp.

Colydiidae: *Bothrideres* (?) *andrewesi* Grouv.

Curculionidae:
- *Apoderus corporaali* Voss.
- *Corigetus* sp.
- *Phytoscaphus triangularis* (Oliv.)

Lyctidae: *Minthea rugicollis* (Walk.)

Ptinidae: *Ptinus fur* (L.)

Scarabaeidae:
- *Aserica* sp., probably *Autoserica*

* This beetle was at first tentatively identified as *Neolepta biplagiata* Jacoby (Corbett 1930; Miller 1930, 1934b).

Chaetadoretus borneensis (Kraatz)
Scolytidae:
A scolytid
Hypothenemus eruditus Westw.
Xyleborus fornicatus Eichh.
Tenebrionidae:
A tenebrionid
Alphitobius laevigatus (F.) [sic]

LEPIDOPTERA

Arbelidae: *Arbela tetraonis* Moore
Arctiidae:
Amsacta lactinea (Cram.)
Olethreutidae:
Eucosma balanoptycha Meyr.
Eucosma conciliata Meyr.
Eucosma defensa Meyr.
Geometridae:
Anisodes obliviaria Walk.
Anisodes obrinaria (Guen.)
Hesperiidae:
Hasora chromus (Cram.) (= *H. alexis* (F.))
Hasora simplicissima mixta (Mab.)
Proteides mercurius pedro (Dewitz)
Limacodidae: *Belippa laleana* (Moore)
Lymantriidae: *Orgyia turbata* (Butl.)
Noctuidae:
Mocis undata (F.)
Spodoptera pecten Guen.
Psychidae:
Mahasena corbetti Tams.
Mahasena sp.
Pyralididae:
Nacoleia diemenalis (Guen.)
Hedylepta indicata (F.)
Maruca amboinalis (Feld.)
Maruca testulalis (Hbn.)
Thyrididae: *Striglina scitaria* (Walk.)
Tortricidae: *Homona coffearia* (Nietn.)

ACARINA

Tetranychidae: *Tetranychus bioculatus* W.-M.

—8-20-38.

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Experimental Diking for Control of Sand Fly and Mosquito Breeding in Florida Salt-Water Marshes

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Sand flies (*Culicoides*) occur in tremendous numbers along the coast of Florida, especially in the long marsh areas of mangrove and pickleweed bordering the Indian River. These bloodsucking midges cause intense annoyance to the residents of this and many other coastal sections, interfering with the success of resorts and the establishment of permanent homes.

This paper reports a partially effective experiment in flooding and impounding water for control of sand flies, and a more effective experiment in diking and drying infested soil for control of both sand flies and salt-marsh mosquitoes. A preliminary note on this work was given by the writers (1935) at a meeting of the Helminthological Society of Washington on February 15, 1935, and the method used for diking a different type of marsh at Savannah, Ga., was reported by Dove & Hall (1934) to the American Society of Parasitologists on December 28, 1934.

METHODS OF DETERMINING SAND FLY ABUNDANCE.—For determining the intensity of breeding and the effectiveness of the control methods, cloth-covered cages were used for capturing sand flies as they emerged from their breeding places, and glass units were used for isolating sand fly larvae from samples of marsh soil (Dove, Hall & Hull 1932; Hull, Dove and Prince 1934).

For the glass isolation units a quart sample of soil was obtained from a marsh area 1 foot square. It was thoroughly mixed by pouring or stirring and allowed to settle overnight in a crystallizing dish. On the following morning the dish was placed in a larger dish, and tap water was poured carefully into the larger dish until the smaller dish was completely submerged. The tap water stimulated the sand fly larvae to swim from the soil, and after three days almost all of them had migrated into the moat formed between the two dishes. From the moat the larvae were easily removed with a pipette and counted.

When it was desired to rear sand flies to adults, they were transferred to soil saturated with clean water that had previously been heated to kill any larvae present. Small particles of fish, fiddler crabs or worms were then added as food. Under laboratory conditions small larvae grew, pupated and produced adult flies

in approximately three months; at low atmospheric temperatures from four to seven months were required for their development.

A simple cloth-covered cage was used on marshes where there was very little tidal water. On areas having several inches of tidal water it was necessary to use two wooden frames of the same size, one above the other, connected with a strip of cloth. The lower frame was anchored in the soil, while the upper one was made buoyant by the attachment of large pieces of cork on the outside. The cork permitted the upper frame to rise and fall with the tidal water, keeping the jar in one of the sides of the frame and the specimens captured in it above the water.

DESCRIPTION OF THE BREEDING AREA.—Sand flies develop in the muck of the salt marshes, and not in the sand along the beaches as is commonly believed. The muck is salty and is saturated with water during the entire period of development of the larvae.

Along the lower portion of the east coast of Florida one finds principally the red mangrove (*Rhizophora mangle*) and the pickleweed or saltwort (*Batis maritima*). In some places the latter grows to a height of 3 feet, hindering drying of the muck and aiding the development of sand fly larvae. The soil in these marshes is black muck, which varies in sand content and contains a large amount of humus near its surface. Where the pickleweed predominates, the soil contains more root masses and is more firm than that found under mangrove trees. White mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia nitida*), glasswort (*Salicornia spp.*), a small amount of spikegrass (*Juncus roemerianus*), sea oxeye (*Borrichia frutescens*), saltmarsh grass (*Spartina spp.*), and leatherfern (*Acrostichum daneaefolium*) occur in noticeable numbers at different places on the east coast of Florida.

It was pointed out in a previous paper (Hull, Dove & Prince 1934) that ditches dug in mangrove and pickleweed marshes for mosquito control concentrated 95 per cent of the sand fly larvae within 10 feet of the ditch banks. The condition resulted from partial drying of the muck farthest from the ditches, especially at low tide. Where there were no ditches, sand fly breeding occurred over extensive areas of low, wet marsh. Owing to the large size of such marshes, the authors were convinced that the drainage ditches, which held water and permitted minnows to feed on mosquito larvae, did not increase sand fly breeding but merely concentrated these larvae near the ditches where the soil was saturated with water the entire year.

FLOODING AND IMPOUNDING OF WATER FOR SAND FLY CONTROL.—Even after the breeding of sand flies was confined principally to the muck near the ditches, the area of infested soil was still too large for economical chemical control. In an effort to restrict the breeding still further, a small mangrove marsh was diked and flooded with water from the Indian River, to determine if sand fly breeding could be confined to a narrow strip of marsh along the edge of an artificial lake. It had previously been shown in the laboratory that very few sand flies would pupate and emerge when the breeding medium was covered with a few inches of water.

Before the diked area was flooded, a number of muck samples were collected, and the location of each sample and the number of larvae present were recorded. Recovery cages equipped with cork were placed over locations found to contain fully developed sand fly larvae.

After one week of flooding there was a marked decrease in the larval population at various places. One month later no larvae were isolated from samples collected from these locations, but a few fully developed larvae were recovered from soil samples taken along the edge of the artificial lake where it had previously been too dry for them to exist. No doubt a great many had been devoured by top-water minnows, because minnows feed on them in the laboratory. The collecting jars in the cages were examined every three days for adult sand flies. No flies were found in these jars after the muck which they covered was inundated.

Throughout the period of the experiment the artificial lake was examined carefully for mosquito larvae. No larvae of the two principal salt-marsh species, *Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.), were found, which was evidently due to their destruction by the large number of minnows present. In one

instance mosquito larvae identified as *Anopheles crucians* Wied. were discovered among some fragments of pickleweed that had gathered at the water surface in a small corner of the lake. They were in a thick mass of débris, and minnows could not possibly reach them.

One serious difficulty was encountered in the flooding of the marsh. Each day the water level was lowered from 1 to 1½ inches by evaporation and seepage. In considering the cost of pumping water to replace this loss, the authors were convinced that flooding of salt marshes was not an economically practical method of control for sand flies and salt-marsh mosquitoes.

DRYING OF MARSHES FOR CONTROL OF SAND FLIES.—The high evaporation and seepages from impounded water suggested experiments to determine if sand flies and salt-marsh mosquitoes could be effectively controlled by drying out the soil of salt marshes. Successful use was made of dikes to exclude tide water, and of pumps and automatic tide gates to remove rain water.

An area north of Fort Pierce, Fla., consisting of approximately 100 acres of mangrove and pickleweed marsh was chosen as the site of these experiments, as it contained almost all the flora found in the southern salt marshes, was fairly typical of southern Florida marshes and in addition was provided with a natural dike on one side. The swamp had been ditched for mosquito control and not for the purpose of drying the soil. It contained a number of small, shallow ponds, or sloughs, that at low tide are ponds of soft muck. Such areas are excellent breeding places for sand flies.

A large ditch approximately 2 feet deep and from 4 to 5 feet wide ran through the middle of the swamp and was connected with smaller ditches 1 to 1½ feet deep and about 30 inches wide. Since the main ditch had been made with charges of dynamite, it was irregular in width and depth. It was cleaned and graded as much as possible to give an average depth of 30 inches. The area from the edge of the ditches to a distance of 10 feet on each side was an ideal breeding place for sand flies. No attempt was made to clean the small ditches.

The natural dike along the east side of the marsh next to the river had been formed by the wind and tides. It was from 15 to 30 feet wide, 3 feet higher than the low-tide mark, and extended the entire length of the experimental plot, a distance of 3,200 feet. So that damage done by fiddler crabs could be studied, at the north end of the plot a dike was constructed by piling muck from the marsh in two parallel rows and filling the space between the rows with sand from the beach. When completed this dike containing a sand core was 10 feet wide, 4 feet above the level of the swamp and 600 feet long. At the south end of the marsh another small dike of muck was constructed 15 feet wide, 4 feet above the level of the swamp and 200 feet long. The two small dikes extended from the natural dike at the river's edge to the high ridges west of the marsh.

Pickleweed covered approximately half the swamp, and white mangrove occurred on about one-fourth of it. Other flora consisted of salt-marsh grass, sea oxeye, glasswort, small patches of red mangrove and leatherfern.

An impeller pump was installed at the south end of the main drainage ditch. This was considered the best type to use where the volume of water was large and where the elevation was only a few feet. The pump had an intake of 12 inches and an outlet of 24 inches. At a speed of 500 revolutions per minute a pump of this type and size will deliver 7,500 gallons of water per minute to an elevation of 5½ feet. The outlet from the pump was placed below tide water, and was operated by an automatic gate which closed with pressure from tidal water and opened with pressure of rain water on the diked area. By this arrangement the pump had to be used only for the water that did not naturally drain through the tide gate. A 6-horsepower, single-cylinder motor was used to operate the pump. Although it did not turn the pump fast enough to maintain its maximum efficiency, it removed the water fast enough to dry the experimental plot.

Previous to the completion of the dikes a number of muck samples were collected at representative locations in the experimental plot. Such locations were marked and records were made of the character of the muck, the amount of shade, the

distance from the mosquito ditches, the salinity of water in the muck and the number of sand fly larvae isolated from the samples. One 1-quart sample of muck contained 1,283 larvae. Three such samples collected 15 to 40 feet from the mosquito ditches did not contain any larvae. Twenty quarts of muck from as many locations contained an average of 155 of the mosquito larvae. Recovery cages placed at different locations also showed that sand flies were emerging from those areas.

One week after the completion of the dikes and removal of tide and rain water by pumping, six muck samples were collected from locations where samples had been previously collected. Two samples taken from wet soil contained two larvae each and the others contained none. Originally the same number of samples taken from these locations had given 701 sand fly larvae. The soil from the four locations giving negative results was only slightly damp.

The swamp was later washed by some good rains, and it was possible to collect wet samples of soil from many low areas. In the first six samples, obtained 12 days after the water had been pumped from the swamp, only eight sand fly larvae were recovered, and they came from two samples of soil collected near the banks of ditches. Samples obtained after this time, even of soil from the ditch near the pump, the last area to become dry, did not contain any larvae. Samples taken beneath the crust formed by the dry soil and from the cracks in the dry soil were likewise negative.

Under the recovery cages the soil was protected from the sunlight, and drying of the soil was delayed. Over a period of 15 days after the water had been pumped from the swamp, 10 cages furnished 105 sand flies. The number gradually diminished until two months after the beginning of the experiment only three adults were obtained from the 10 cages, and after that time none was obtained.

The drying of the marsh was accompanied by a reduction in the abundance of sand flies, and both soil samples and recovery cages show that this operation was responsible for the destruction of the immature stages of sand flies.

EFFECT OF DIKING ON MOSQUITO BREEDING.—In the salt-marsh areas of St. Lucie County, Fla., excellent results in mosquito control have been obtained, under normal conditions, by the construction of a system of narrow, parallel ditches. These ditches serve to drain flood water from the surface and to admit minnows to the interior of the marsh. In the mangrove areas the ditches function satisfactorily, as this growth does not prevent entrance of the minnows when the marshes are flooded. In the tall pickleweed, however, a different situation exists. The pickleweed growth is so dense that minnows are unable to penetrate it when tide water overflows to only a half inch or so. Under these conditions, which have been described as trickle tides, heavy mosquito production is apt to occur even in a ditched area, and the use of dikes and pumps for drying the swamp appears to be a promising method of control.

Observations of the diking experiment in St. Lucie County have shown that the excess water from rains and tides could be removed from the diked area by pumping in sufficient time to prevent development of mosquito larvae. This was demonstrated on one occasion when mosquito larvae occurred in a marsh adjoining the diked experimental plot. The results indicate that a system of dikes and pumps should prove a feasible and effective method of controlling mosquitoes under the conditions encountered at Fort Pierce, Fla.—8-25-38.

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Studies of Control Measures for Sweetpotato Weevil in Louisiana

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The continued spread of the sweetpotato weevil, *Cylas formicarius* (F.), and the enormous losses occasioned by this pest have caused great concern to the growing sweet potato industry. A most rigid system of inspection and certification of shipment is being enforced in Louisiana and an intensive clean-up and eradication campaign has been undertaken by both the state and federal agencies. It is evident that such a campaign cannot be fully successful unless it is based on effective control measures.

The use of weevil-free seed potatoes has long been recognized as the first and most important measure for control of this insect. Most of the investigations to date have been aimed at this objective. The use of carbon bisulphide and the burning of sulfur, recommended in the earlier publications, have produced serious injury. Therefore these materials cannot be safely employed. The only practical method of disinfesting seed sweet potatoes known at present and one extensively used during the last two years is the use of paradichlorobenzine as recommended by Cockerham & Deen (1936). This method, however, requires a 21-day period of treatment in an airtight container or dirt bank, leaves an unpleasant odor in the potatoes and seriously retards the germination.

Investigations into the possibilities of cold-water treatment were started by the writer in January, 1937, when the construction of a suitable greenhouse at Sunset, La., gave proper facilities for testing out germination of sweet potatoes following different treatments. Later, experimental work was conducted into the possibilities of fumigation, aimed at finding a satisfactory fumigant both from the standpoint of seed disinfestation for the average small farmer and for fumigation of commercial shipments and storage. It is considered desirable to publish at this time the data obtained during the period November 1, 1936, to August 21, 1937, on the effectiveness of certain extremely promising materials.

CHEMICAL SOLUTIONS AND EMULSIONS USED AS COLD-WATER TREATMENTS.—A series of preliminary experiments was conducted during January to test the effect of complete submergence of seed sweet potatoes in cold water. A bushel of weevil-infested potatoes was placed in each of four barrels and kept completely submerged in water by being weighted. At the end of 24-hour periods a bushel was taken out, a portion of it bedded for germination and the remainder dissected. The dissected-out weevils were placed on a piece of slightly moistened blotting paper and retained in Petri dishes for observation. Sweet potatoes submerged for 48 hours gave a fine, stimulated germination, showing the beneficial effect of dipping for that period. A 72-hour submergence showed a slightly poorer germination, and in longer periods of submergence decided injury occurred. These experiments showed that the weevil in all stages in the potatoes survived submergence in cold water for as long as five days, all reviving within a few hours. A later test showed that they could survive submergence in "mulsoid-sulfur" solution as long as six days. This demonstrates clearly that the weevil requires very little oxygen to sustain itself over long periods of time in the sweet potato.

With these data available, numerous tests were made with various chemical solutions and emulsions from January to the middle of May, as long as suitable material could be obtained. From 20 to 25 pounds of weevil-infested sweet potatoes were used for each test, placed in a burlap sack and completely submerged in 5 gallons of the diluted material in crocks in the greenhouse. Results of these preliminary toxicity tests have been briefly summarized in table 1, only those solutions being listed which showed a definite high toxicity against the weevil.

All of the materials in table 1 were demonstrated to be non-toxic to sweet potatoes except the methyl bromide (25 per cent in methyl alcohol). It is thought, however, that smaller dosages of this material will also prove to be effective against the weevil without causing injury.

The following solutions at varying strengths were also tested against the weevil but were found either to injure the potatoes or to be relatively ineffective: sodium hypochlorite, thiodiphenylamine, copper sulfate, zinc sulfate, hydrated lime, potassium sulfate, sodium borate, Chlorine and ammonium compounds proved completely negative. Weak acid solutions such as oxalic acid caused immediate break-down of the sweet potatoes. Lime sulfur solutions gave a relatively high kill of the weevil but caused bleaching and break-down of the potatoes

Table 1.—Preliminary tests on *Cylas formicarius* in seed sweet potatoes, Sunset, La., 1937.

Dipping Solution	Number of Hours Submerged	Number of Weevils		Per Cent Kill
		Dead	Alive	
Orthodichlorobenzine emulsion				
7 oz. to 5 gal. water	50	59	29	67.04
15 ozs. to 5 gal. water	48	8	28	22.20
Dichlorpentane emulsion				
10 oz. to 5 gal. water	48		11	0.00
10 oz. to 2½ gal. water	72	18	7	72.00
Chlorpicrin emulsion				
3½ oz. to 5 gal. water	48	21	1	95.50
Ethylene dichloride emulsion				
15 oz. to 5 gal. water	24	7	8	46.70
15 oz. to 5 gal. water	67	71	53	57.30
15 oz. to 5 gal. water	72			100.00
25 oz. to 5 gal. water	28	52	3	94.50
Ethylene dibromide emulsion				
12 oz. to 1½ gal. water	26	34	24	58.60
12 oz. to 1½ gal. water	48	34	1	97.10
Carbon bisulfide emulsion				
15 oz. to 5 gal. water	48	32	0	100.00
15 oz. to 5 gal. water	48	73	0	100.00
30 oz. to 5 gal. water	18	29	5	87.90
Same old solution used	28	38	0	100.00
10 oz. to 5 gal. water	48	39	0	100.00
Same old solution used	31	31	0	100.00
10 oz. to 5 gal. water	48	240	0	100.00
5 oz. to 5 gal. water	48	25	0	100.00
5 oz. to 5 gal. water	24	17	63	21.20
40 oz. to 20 gal. water	48	104	26	80.00
15 oz. to 5 gal. water	37¾	59	0	100.00
Carbon tetrachloride emulsion				
15 oz. to 5 gal. water	54	31	4	88.60
25 oz. to 5 gal. water	48	20		100.00
Sodium lauryl sulfate				
5 oz. to 5 gal. water	54¼	13	3	81.30
5 oz. to 5 gal. water	48	36	22	62.00
10 oz. to 5 gal. water	27	25	7	78.10
Dichlorethyl ether				
10 cc. to 1 gal. water	24		104	0.00
10 cc. to 1 gal. water	48	65	113	36.50
Methyl bromide (25% in methyl alcohol)				
500 g. to 7½ gal. water	24	163	0	100.00

Sulfocide, Bordeaux mixture, mulsoid sulfur, and sodium dinitro-o-cyclohexylphenate. Such powerful contact solutions as nicotine sulfate and pyrethrum and rotenone extracts gave completely negative results but seemed to stimulate germination slightly. *Lethane 440* showed only slight toxicity to weevil and killed the potatoes. Sodium hypochlorite gave almost negative results but stimulated germination to a remarkable degree. also. Such larvicides as thiodiphenylamine, sodium dinitro-o-cyclohexylphenate and dichlorethyl ether showed little indication of toxicity against the weevil.

Early during the investigations it became necessary to make emulsions of certain materials such as orthodichlorobenzine, carbon bisulfide, ethylene dichloride, carbon tetrachloride, dichlorpentane and chlorpicrin. For this purpose the emulsifier *E25-61* (Eddy 1936) proved highly

satisfactory, being comparatively cheap, rather stable and easily mixed with only slight agitation. Of these, the dichlorpentane emulsion showed the least toxicity and the carbon bisulfide the greatest. While both the ethylene dichloride and the carbon tetrachloride emulsions gave a high mortality, the dosage and time both had to be greatly increased over that required to obtain the same kill by use of the carbon bisulfide emulsion. The chlorpicrin emulsion was easily emulsified and gave a high kill but is too dangerous and difficult to handle for further consideration in this connection.

FIG. 1.—Effect of complete submergence in water on germination of sweet potatoes for (1) 48 hours, (2) 72 hours, (3) 96 hours and (4) 120 hours. Treated January 6–11 and photographed February, 1937.

CARBON BISULFIDE EMULSION.—Of all the numerous cold-water solutions investigated to date, carbon bisulfide emulsion stands out as the most promising practical material to disinfest seed sweet potatoes prior to bedding. During the period from February 24 to April 12, 1937, several dozen experiments were conducted with the carbon bisulfide emulsion, all of which proved this solution to be extremely toxic to all stages of the sweetpotato weevil. A dozen different treated lots have shown excellent germination on the greenhouse bench. The rotten-egg odor of the freshly treated potatoes is completely dissipated by the second day and when they are eaten raw, or baked in the oven the natural sweet flavor is unimpaired. The exact action of this gas is not thoroughly understood. It penetrates throughout the potatoes and most of the larvae, upon dissection of the potatoes, are found to be stiff and fully distended, manifesting symptoms quite similar to those of paralysis. In the few cases where the treatment was not fully effective, the larvae manifested a slight twitching evident on the fourth day, showing a gradual wearing off of the effects of the treatment. That these few individuals could recover sufficiently to resume work is considered highly questionable.

FUMIGATION METHODS.—A standard cylindrical vacuum chamber of 50 cubic feet capacity, a vaporizer and equipment were available for the fumigation work. All but a few of the experiments were conducted in this steel chamber at atmospheric pressure and without forced circulation of air. A few vacuum tests were made with methyl bromide but were discontinued as it was thought more desirable to direct every effort at finding a fumigant that could be successfully used in any kind of air-tight container or room. Several satisfactory tests were made in a specially constructed wooden box of 100 cubic feet capacity.

The early tests were conducted with kiln-dried sweet potatoes, but late in the spring the infested potatoes available became very porous. Undoubtedly the gases can penetrate the drier and more porous potatoes more easily than they can solid stock. A large number of culled, infested potatoes were placed in cold storage, kept at 50 degrees to 60 degrees F. and gradually withdrawn and used in the later

experiments as needed. During the late spring, artificial propagation of the weevils was allowed to take place indoors in screened cages so as to have infested material with which to work during the slack period. For each experiment, from one-half to two bushels of weevil-infested potatoes and several crates of sound potatoes were used together. The latter were retained in each case to see the effect of these tests a 100 per cent kill of the weevils was obtained. An exception occurred on November 6, 1936, in a test in which 3 ounces of HCN to the 50 cubic foot chamber were used for one hour exposure at 70 degrees F. with 25-inch vacuum, when several pupae survived.

METHYL BROMIDE.—This material proved to be the quickest and most effective of the compounds tried against the

Table 2.—Experiments at atmospheric pressure with fumigants against *Cylas formicarius*, Sunset, La., 1936–37.

Experiment No.	Number of Bushels Dissected	Dosage Per 50 Cubic Feet	Hours Exposed	Larval Mortality: Total Larvae Used	Larval Mortality: No.	Larval Mortality: Per Cent	Total Pupae Used	Pupal Mortality: No.	Pupal Mortality: Per Cent	Total Adults Used	Adult Mortality: No.	Adult Mortality: Per Cent	Entry Temperature
						Methyl Bromide							
1	1¼	5.00 cc.	24	1	0	0.0	25	4	82.6	37	35	94.5	
2	½	20.28 cc.	24	—	—	—.0	1	1	100.0	27	27	100.0	
3	3	32.44 cc.	24	8	8	100.0	11	11	100.0	64	64	100.0	
4	2	10.10 cc.	24	—	—	—	4	4	100.0	74	74	100.0	82°F.
5	3	10.10 cc.	24	3	3	100.0	9	9	100.0	24	24	100.0	80°F.
6	1	15.30 cc.	24	326	326	100.0	235	235	100.0	166	166	100.0	83°F.
7	1	7.59 cc.	24	382	382	100.0	233	233	100.0	109	109	100.0	92°F.
8	1	10.10 cc.	24	742	742	100.0	278	278	100.0	263	263	100.0	92°F.
9	2	15.30 cc.	18	424	424	100.0	515	515	100.0	763	763	100.0	82°F.
10	2½	15.30 cc.	12	116	116	100.0	162	162	100.0	133	133	100.0	89°F.
11	2	5.00 cc.	12	746	746	100.0	1226	1226	100.0	1327	1327	100.0	88°F.
						Ethylene Dichloride and Carbon Tetrachloride Mixture							
1	2	16 oz.	24	116	116	100.0	32	32	100.0	41	41	100.0	
2	1	8 oz.	24	1961	1869	95.3	58	58	100.0	17	17	100.0	
3	½	12 oz.	24	26	26	100.0	32	29	96.6	31	31	100.0	
4	1	12 oz.	18	123	123	100.0	34	34	100.0	67	67	100.0	
5	½	12 oz.	24	191	190	99.4	143	139	97.2	210	209	99.5	85°F.
6	1	18 oz.	24	64	64	100.0	60	60	100.0	10	10	100.0	85°F.
						Trichlorethylene							
1	1	12 oz.	24	53	53	100.0	99	99	100.0	25	25	100.0	81°F.
2	3	12 oz.	24	878	878	100.0	539	539	100.0	281	281	100.0	82°F.
3	1	12 oz.	18½	380	380	100.0	115	110	95.6	113	113	100.0	89°F.
4	2	12 oz.	12	248	244	98.3	56	56	100.0	39	38	97.4	89°F.
5	2	12 oz.	12	220	188	85.4	390	320	82.0	243	190	78.1	89°F.
						Tetrahydronaphthalene							
1	1	12 oz.	24	10	0	0.0	19	0	0.0	216	0	0.0	

the gas on germination and keeping qualities. The weevils dissected out were retained for observation for at least a week.

VACUUM FUMIGATION.—After tests showed that a sustained vacuum up to 28½ inches produced no injurious effect on the sweet potato, a series of experiments was conducted in which 1 to 3 ounces of liquid hydrocyanic acid to the 50 cubic foot chamber were used for one hour at various degrees of pressure. All bruised areas on newly dug potatoes showed up immediately as sunken areas, but the kiln-dried potatoes remained of excellent appearance. These, however, when broken on the fifth day following the fumigation, gave off a sickening sweet, pumpkinlike odor, showing an internal change due to the effects of the gas. By the tenth day all the potatoes had turned brown, and break-down was evident. In nearly all of weevil. It is a liquid at low pressure, with a specific gravity of 1.732 and boiling point of 4.6 degrees C., and comes in returnable steel cylinders. As low a dosage as 5 cubic centimeters or 0.3 ounce of methyl bromide to 50 cubic feet gave 100 per cent kill in a 12-hour exposure at 88 degrees F. As shown in table 2, a 100 per cent mortality has been consistently obtained with very small dosages at the existing rather high temperatures. Disastrous results occurred when 20 cubic centimeters or 1.2 ounces to the 50 cubic feet were tried.

Difficulty was experienced in measuring out and handling this material, and satisfactory types of simple applicators must be developed. Caution must be taken by the operator of the possible poisonous accumulated effect of this gas with continuous usage. Sweet potatoes treated

with methyl bromide give off a smoky odor, but this is quickly dissipated. All stages of the weevil turn somewhat yellow in appearance following treatment with this gas and the effect is accumulative. Therefore, dissection of the potatoes was delayed for at least several days after treatment to determine more accurately the results. The pupal stage of the weevil proved to be the most difficult to kill.

MIXTURE OF ETHYLENE DICHLORIDE AND CARBON TETRACHLORIDE.—A liquid mixture of ethylene dichloride (75 per cent by volume) and carbon tetrachloride (25 per cent by volume) was poured over burlap sacks placed on top of the crates and quickly evaporated. This gas is heavier than air, readily descends and diffuses throughout the space, and kills by anesthetizing.

As shown in table 2, a dosage of 12 ounces of the mixture per 50 cubic feet with an exposure of 24 hours has given a consistent 100 per cent mortality of all stages of the weevil. Potatoes treated with this material have retained their normal color and have shown excellent germination. By the second day following treatment, no perceptible odor is left in the potato, which can be eaten raw, the natural sweet, woody flavor being retained. The results of the treatment with this gas are most conclusive as the larvae immediately turn greenish and decomposition quickly takes place. The pupae remain whitish for several days but their abdomen and wing pads are distended.

TRICHLORETHYLENE.—Liquid trichlorethylene was poured over burlap sacks placed on top of the crates. This material is cheap and easily handled but is unquestionably less toxic to the weevil than either the mixture of ethylene dichloride and carbon tetrachloride or methyl bromide. Five tests with this gas indicate a distinct toxicity to all stages of the weevil but gave somewhat variable results. Several tests with a dosage of 12 ounces per 50 cubic feet and an exposure of 24 hours at 81–82 degrees F. gave 100 per cent mortality. An attempt to shorten the period to 12 hours gave an unsatisfactory kill. Trichlorethylene has a specific gravity of 1.462 and a boiling point of 86.7 degrees C. It kills by anesthetizing, and several days should pass before dissections are made to determine the results. Both the larvae and the pupae remain whitish for some time and make it difficult to determine the mortality. No perceptible odor is left in the sweet potato following treatment, and germination is uneffected.

TETRAHYDRONAPHTHALENE.—This liquid was applied by being poured on burlap sacks but it volatilized very slowly. A single test was made in which 12 ounces to 50 cubic feet were used with an exposure of 24 hours. The bushel of potatoes dissected from this test yielded 10 larvae, 19 pupae and 216 adults, 100 per cent negative. A very disagreeable odor persisted in the treated potatoes for days.

SUMMARY AND CONCLUSIONS.—For the small farmer who does not have an airtight room or chamber it now appears practical to disinfest his seed sweet potatoes by completely submerging them for 48 hours in barrels containing a solution of 3 ounces of carbon bisulfide emulsion per gallon of water. This emulsion is made by mixing $1\frac{1}{4}$ ounces of *E25-61* emulsifier to 9 ounces of carbon bisulfide. An excellent emulsion is quickly made with only slight agitation. Indications are that the freshly made emulsion is far more effective than one mixed for some time and that the above dosage and time element can be reduced somewhat and the emulsion still be effective under most conditions. The sulfated alcohol, sodium oleyl sulfate, is a cheap and effective emulsifier for carbon bisulfide that can also be used (Cory & Langford 1935).

Potatoes treated by the cold-water dip method break down if allowed to stand in the hot sun or if planted too deep in a saturated condition. They should be covered with only a few inches of soil when bedded out except during periods of possible freezing temperatures. It is thought that the carbon bisulfide emulsion is toxic to spores of black rot and other diseases but, if not, then some compatible fungicide may have to be incorporated in the dip. This vital point should be carefully investigated and a further series of experiments at various temperatures carried out before general recommendations can be made.

During the course of the work three different gases, namely, methyl bromide, a mixture of ethylene dichloride and carbon tetrachloride, and trichlorethylene, proved to be extremely toxic to all stages

of the weevil. Low solubility in water and high boiling points of these gases probably account for their ability to penetrate quickly through the weevil tunnels in the moist sweet potato and kill effectively. All three are cheap at the concentrations necessary, non-inflammable, non-explosive, reasonably safe for the operator, and have no injurious toxic effect on the dormant sweet potato. In the case of the sweet potatoes starting to sprout, the red shoots may be scorched back by the treatment but the vitality is uninjured, fig. 2.

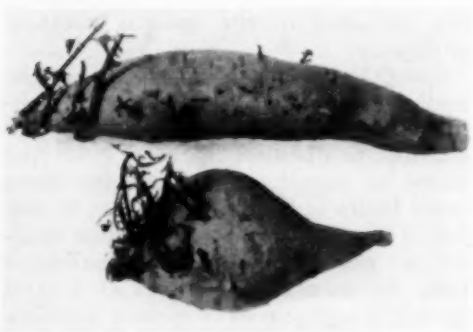

FIG. 2.—Sweet potatoes fumigated for 24 hours at atmospheric pressure on June 24; 10 centimeters or three-fifths ounce methyl bromide to 50 cubic foot chamber at 92 degrees F.: 100 per cent kill of all stages of weevil was obtained, but red sprouts at time of treatment were scorched back. Photographed August 6, 1937, to show uninjured vitality and new sprouts.

Methyl bromide is without question the most quickly acting and most toxic of the fumigants tested. When satisfactory types of simple applicators become available, this gas should prove to be the most satisfactory for fumigation of sweet potatoes before storage in kilns and for carload fumigation. It would appear feasible to fumigate loaded refrigeration cars and permit certified movement, but the practicability of this must be carefully worked out, as indiscriminate use of methyl bromide may result in a total loss.

For the farmer, the mixture of ethylene dichloride and carbon tetrachloride at the rate of 12 ounces to 50 cubic feet for 24 hours is recommended for trial. This material is cheap, readily available and simple to handle. While it can be readily evaporated in shallow pans placed on top of crates, it is suggested that the amount to be used be poured over several burlap sacks which are then suspended by a hook from the ceiling. Care must be taken not to let this liquid fall on the potatoes, as it produces injury.

Trichlorethylene is unquestionably less toxic than the above two gases and distinctly slower in action. It therefore is not considered further.

The results of this preliminary work with fumigants would indicate that either methyl bromide or the mixture of ethylene dichloride and carbon tetrachloride will give a satisfactory kill when used in any air-tight room or container at ordinary atmospheric pressure at temperatures of 80 degrees F. or above. Further experimental work with numerous replications should be carried out and effective dosages must be accurately determined for the lower temperatures prevailing during February and March, at the time of seed disinfestation. For commercial shipments a slight speeding up of the process of fumigation can be obtained by the use of vacuum. The high cost of large vacuum tanks and equipment and necessary expert supervision at each major shipping point that such a system would entail would certainly seem to be unwarranted. —9-9-38.

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THE Secretary of Agriculture has announced a revision of the quarantine and regulations relating to the pink bollworm of cotton, effective March 15, 1939. No change was made in the areas under regulation, which now include 6 entire counties and part of another in Arizona, 12 in New Mexico and 35 counties and parts of 2 others in Texas. The purpose of the revision is chiefly to clarify the requirements. To meet the need for a more flexible means of administering the requirements, the Chief of the Bureau of Entomology and Plant Quarantine is authorized by this revision of the quarantine to modify by administrative instructions the restrictions, in accordance with the facts as to pest risk.

Possible Changes in Ratio of Lead to Arsenious Oxide in Lead Arsenate Residues on Apples

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Investigators of lead arsenate injury to fruit and foliage have shown this injury to be caused by soluble arsenic in the spray mixture or in residues from spray mixtures. McDonnell & Graham (1917) showed the conversion of acid lead arsenate to basic lead arsenate to be possible in distilled water according to the following reaction:

$$5PbHAsO_4 + HOH \rightleftarrows Pb_4(PbOH)(AsO_4)_3 + 2H_3AsO_4$$

By this reaction the ratio of lead to arsenious oxide is changed from 2.09 to 1 in $PbHAsO_4$ to 3.49 to 1 in $Pb_4(PbOH)(AsO_4)_3$. More recently Ginsburg (1937) measured the decomposition of acid lead arsenate in hard waters. From the data presented in these publications it would be natural to assume that in most spray deposits there is a conversion of acid lead arsenate to basic lead arsenate and that the degree of such conversion can be measured by the change in ratio of lead to arsenious oxide in the deposits. Experiments were undertaken in southern Indiana in 1935 and 1936 to determine the rate of decomposition of acid lead arsenate in spray residues.

METHODS OF STUDY.—Samples of apples and apple foliage were analyzed for lead and arsenious oxide immediately after being sprayed and other samples from the same trees were analyzed after various periods of weathering. All samples were analyzed in duplicate, both lead and arsenious oxide determinations being made on each duplicate. In 1935 fruit only was analyzed and duplicate 25-fruit samples were taken; in 1936 analyses were made of similar samples of both fruit and foliage. No spray was applied between the first and second analyses. From these analyses the ratios of lead to arsenious oxide were calculated. The same brand of acid lead arsenate was used in the spray plots during the two seasons; the ratio of lead to arsenious oxide in the two lots averaged 2.08, or slightly less than the ratio in the theoretically pure product.

The arsenious oxide was determined by the bromate method (Association of Official Agricultural Chemists 1933; Jones 1934) of arsenic trichloride distillation and bromate titration. The lead residues were determined by the methods discussed by Wichmann and coworkers (1934). In 1935 the lead was isolated by sulfide precipitation, then electrolytically deposited as the peroxide and finally dissolved in sodium acetate, acetic acid and potassium iodide reagent, and the liberated iodine titrated with sodium thiosulfate. In 1936 the lead was isolated by the diphenylthiocarbazone method, with final determination as in 1935.

Table 1.—Precipitation records during the growing season, 1935 and 1936, and average for 45-year period, 1885–1930.

	Precipitation in Inches		
Month	1935	1936	Average for 45-Year Period
May*	7.40	0.99	4.04
June	6.32	1.91	4.47
July	2.25	3.47	3.60
August	5.19	1.92	3.61
September†	0.74	0.48	3.75
Total	*21.90*	*8.77*	*19.47*
Length of growing season, days	127	115	153
Daily precipitation, inches	0.17	0.08	0.13

* 19 days in 1935; 20 days in 1936.
† 16 days in 1935; 3 days in 1936.

WEATHER CONDITIONS.—The degree of weathering to which the samples were exposed is shown by the precipitation records for the two seasons, table 1. In 1935, the daily precipitation for the growing period was 0.04 inch above and, in 1936, 0.05 inch below that for the 45-year period, 1885–1930. Thus it is apparent that these samples were taken during periods of drought and near-flood conditions.

SPRAY TREATMENTS AND ANALYTICAL DATA.—The spray schedules in the plots sampled were as follows:

Table 2.—Ratios of lead to arsenious oxide in spray residues on fruit before and after weathering following the various spray applications, 1935.

Weathering Period in Days	Plot 1		Plot 2		Plot 3	
	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering
12	—	—	2.02*	2.74*	—	—
12	2.03	2.11	2.22	2.21	2.35	2.03
13	2.19	2.32	2.23	2.36	2.26	2.26
9	2.32	2.11	2.38	2.28	1.87	2.29
19	2.01	2.10	2.11	2.34	2.16	2.05
11	1.97	1.90	2.16	2.02	2.04	2.04
13	1.91	2.09	1.72	2.40	2.16	2.13
30	2.11	2.08	2.33	2.13	2.18	2.00
Mean	*2.08*	*2.10*	*2.15*	*2.31*	*2.15*	*2.11*

* Preseason lead arsenate spray.

1935

Plot 1.—Lead arsenate plus Bordeaux, 7 cover sprays.

Plot 2.—Lead arsenate plus mineral oil plus lime, 6 cover sprays; lead arsenate plus Bordeaux, 1 cover spray.

Plot 3.—Lead arsenate plus mineral oil plus soap plus lime, 4 cover sprays; lead arsenate plus Bordeaux, 5 cover sprays.

1936

Plot 1.—Lead arsenate plus Bordeaux, 8 cover sprays.

Plot 2.—Lead arsenate plus Bordeaux, 10 cover sprays.

Plot 3.—Lead arsenate plus Bordeaux plus kerosene plus triethanolamine oleate, 4 cover sprays; nicotine plus oil, 4 cover sprays.

Plot 4.—Lead arsenate plus Bordeaux plus kerosene plus triethanolamine oleate, 4 cover sprays; nicotine peat, 4 cover sprays.

Samples were taken after each cover spray on plots 1 and 2 of 1935 and plot 1 of 1936 and after most of the cover sprays on the other plots.

The results of the analyses are shown in tables 2 and 3.

Discussion.—In 1935 the ratio of lead to arsenious oxide in residues averaged 2.15, or 3.3 per cent higher, and in 1936 it was 2.11, or 1.4 per cent higher than that in the original spray material. The fact that the lead sulfide method of isolating lead residues is both less exact and less precise than the diphenylthiocarbazone method probably accounts for this difference and for the greater extremes of ratios for 1935.

A comparison of the ratios immediately after spraying with those after weathering shows no consistent differences. In 1936, when there were 75 days between the two samplings, the ratio of lead to arsenious oxide in the residue did not increase. A statistical examination of the data for both years showed no significant differences between the two samplings.

The variations between the ratios are

Table 3.—Ratios of lead to arsenious oxide in spray residues on fruit and foliage before and after weathering following the various spray applications, 1936.

Weathering Period in Days	Plot 1				Plot 2				Plot 3		Plot 4	
	Fruit		Foliage		Fruit		Foliage		Fruit		Fruit	
	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering	Immediately After Spraying	After Weathering
4	—	—	—	—	—	—	—	—	2.02	2.18	2.02	2.18
8	1.97	2.13	2.13	2.15	—	—	—	—	1.95	2.03	2.14	2.06
6	2.02	1.98	2.34	2.27	2.02	2.14	2.30	2.14	2.10	2.13	2.07	2.13
9	2.22	2.32	2.14	2.22	2.21	2.25	1.95	2.17	2.17	2.18	2.23	2.20
18	2.22	2.15	2.17	2.05	2.07	2.13	2.07	2.05	—	—	—	—
12	2.09	1.87	2.07	2.16	2.03	2.22	2.13	2.13	—	—	—	—
12	2.19	2.07	2.04	2.03	2.15	2.16	2.16	2.07	—	—	—	—
13	2.12	2.19	2.06	1.99	2.13	2.12	2.05	2.15	—	—	—	—
28	1.98	2.03	2.16	2.07	2.07	2.11	2.09	2.18	—	—	—	—
64	—	—	—	—	—	—	—	—	—	—	2.09	2.07
75	—	—	—	—	—	—	—	—	2.20	2.04	—	—
Mean	*2.10*	*2.09*	*2.13*	*2.12*	*2.10*	*2.16*	*2.11*	*2.13*	*2.09*	*2.11*	*2.11*	*2.13*

in reality the combined analytical errors of the methods employed. It is estimated that the analytical error of the bromate method for arsenic may amount to as much as 3 per cent of the mean and that the methods for determining lead are only slightly better.

The findings reported in this paper are contradictory to the results of early investigations of spray residues. Hartzell & Wilcoxon (1928) reported analyses of 20 samples of sprayed fruit in which the ratio of lead to arsenious oxide averaged 9 to 1, whereas Marshall & Ford (1933) reported investigations, conducted from 1929 to 1932, showing an average ratio of about 5 to 1. McLean & Weber (1933, 1934) in two publications reported average ratios of 2.4 to 1 and 3.0 to 1. More recently these authors with Driggers & O'Neill (1937) reported the analyses from eight spray plots at harvest in which the ratio of lead to arsenious oxide averaged 5.7 to 1. In recent studies of spray residues Harman (1937) and Frear & Worthley (1937) reported ratios averaging 2.2 to 1 and 2.8 to 1, respectively. Pearce & Avens (1938) report a study of the ratio of lead to arsenious oxide in lead arsenate residues on harvested fruit. Except in instances where the residues were allowed to weather in excess of 80 days the ratios reported in this paper are not greater than 2.5 to 1. Where only a calyx spray of lead arsenate was applied and the residues weathered 120 days, ratios of 3.0 to 1 and 3.6 to 1 are reported. Pearce & Avens compared the ratios obtained at harvest to those of pure acid lead arsenate ($PbHAsO_4$) and concluded that arsenic weathers more rapidly from spray residues than does lead. Had the ratios at harvest been compared to the ratio of lead to arsenious oxide in freshly deposited residues it is improbable that significant differences would have been found. The residue studies by Hartzell & Wilcoxon were on inadequate samples (4-fruit), the maximum residue being only 0.193 milligram of arsenious oxide per kilogram of fruit (0.0014 grain per pound). The high ratios of lead to arsenious oxide reported are probably the result of the employment of methods that were unreliable or unsuited to the range of residues studied. The development of more precise methods for analysis of spray residues has shown the inadequacy of the methods of analysis and sampling technique used in the early investigations.

SUMMARY.—Experiments were undertaken in southern Indiana in 1935 and 1936 to determine the extent of decomposition of lead arsenate spray residues on apples as measured by their ratios of lead to arsenious oxide. The residues were analyzed immediately after the various cover-spray applications and again after the residues had weathered. A total of 248 samples of apples and apple foliage were used.

The average ratio of lead to arsenious oxide in these samples did not vary significantly from that in the original spray material, and samples taken immediately after spraying showed no significant difference from those taken after weathering. The slight variations between the ratios are in reality the combined analytical errors of the methods of residue analysis. The high ratios obtained by early investigators are due probably to inadequate samples or to unreliable methods of analysis.—9-16-38.

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Life Cycle and Food Requirements of the Northern Grain Wireworm, *Ludius aereipennis destructor* Brown

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Studies on the habits and methods for the control of the northern grain wireworm, *Ludius aereipennis destructor* Brown, were commenced at the University of Alberta in 1925. From these it was possible, by 1927, to give the broad outlines of the life cycle together with promising methods for reducing their numbers in grain fields by employing cultural methods (Strickland 1927). It was, at that time, realized that the life cycle of this very destructive insect probably would prove to be much longer than the two to four years with which many wireworms were credited. Furthermore, there was every indication that individual wireworms varied greatly in their rate of development even when they were kept under approximately identical conditions.

Experiments were planned, therefore, to ascertain, in so far as was possible, how extreme the variations in these respects might be.

In addition to the investigation of many other factors of importance in connection with control, a study was made at the same time of the food requirements of the larvae throughout their lengthy period of development, particularly during the remainder of that summer in which they emerged from the eggs. It had been ascertained that these larvae could be fairly readily starved in their first two instars even though the more mature wireworms could live for several years without access to living vegetation. The late Norman Criddle had informed me that he had kept a partly grown larva of this species, which he had picked up in the field in Manitoba, for a number of years in a box containing damp soil only. It finally matured. In the course of our investigation we kept half-grown wireworms in similar boxes for two and a half years. These moulted and increased in size. Upon dissection, one was found to have humus in its stomach. Despite the fact that half-grown wireworms feed, in the field, on a great variety of plants we were unable to ascertain their relative food value. The food requirements of recently emerged larvae were, however, more readily discovered.

METHODS OF STUDY.—Three types of cages were designed for the purpose of obtaining definite information on food requirements and the length of the life cycle.

1. A cage in which the reactions of individual wireworms to food could be studied under the binocular microscope without disturbing them. This consisted of a small glass cylinder, 3 inches long by 1 inch in diameter. At 1 inch from the top of the cylinder a plaster of Paris false bottom was constructed so that a small breeding cage would be formed above it. The upper surface of the plaster was painted with India ink in order to render the minute white larvae more conspicuous against a black background. The cylinder was filled below the false bottom with damp sand and was, itself, inserted in a container filled with similarly dampened sand. Recently emerged larvae, together with germinating seeds of the vegetation which was being tested for its food value, were placed in the cage, which was then

closed with a cork. At any time these cages could be removed from their container and their contents be examined under the binocular microscope.

Difficulties were soon experienced. First instar larvae, particularly when they are not covered with soil, show decided negatively geotropistic responses and have a tendency to ascend the walls of the cage. When the cage was tightly closed with a cork, carbon dioxide given off from moderately large germinating seeds quickly immobilized the larvae. In addition, variations in temperature frequently drew free water from the underlying sand and flooded the cage. Both troubles were reduced by inserting through the cork, a short piece of glass tubing, which was lightly plugged with cotton in order to deter the escape of larvae.

These cages, though not very satisfactory, served a useful purpose in presenting opportunities for making observations which are impossible while larvae inhabit their normal habitat beneath the surface of soil.

2. A wide-mouthed one-pint sealer. This, also, was provided with a plaster false bottom, constructed over a layer of about an inch of sand which was kept moist by means of two pieces of glass tubing which had been inserted through the plaster before the latter set. Water was introduced through one of these tubes, and the other served for the escape of displaced air. The cage, above the plaster, was partly filled with earth in which the vegetation under test was grown and into which the larvae were later introduced.

In these cages the extent of feeding upon the roots or stems of the plants could be recorded. An occasional examination of the soil enabled us to observe the progress of the larvae themselves.

3. Field cages. These consisted of galvanized iron cylinders, 12 inches long by 6 inches in diameter. In this respect they resembled those described by Lane (1924) for this purpose. The bottom edge of each was turned inwards and upwards to form a trough which held in position a false bottom of plaster. The latter precluded the escape of wireworms and the entrance of "undesirable aliens" through the bottom of the cage. It did not, however, affect the free movement of moisture between the soil with which the cage was filled and that of the field in which it was placed. As a further deterrent to visitors (ground beetles were most persistent in attempting to enter) a close fitting cylinder of galvanized wire screen, 3 feet high, was fitted around the top 2 inches of the cage, which projected above the soil.

Of some 80 cages of this type, practically all stood up perfectly throughout the eight years required for the completion of this experiment. A few very strongly rooted plants broke through the plaster bottom but, apart from this, failures were due only to an occasional accident.

During the first few years of the experiment the cages were lifted twice a year, as early as possible in the spring and after the first few frosts in the autumn. The soil was sifted and all wireworms present were measured and returned, with the original soil, to the cage. As soon as observations showed that there was no winter mortality or development the spring examination was discontinued.

In addition to these series of cage experiments, recently hatched larvae were confined, individually, in 2-ounce tin cans which contained a little moist soil and one or two grains of germinating wheat. These were examined weekly and, at each examination, the food was replaced. The extreme variation in individual feeding habits, in the frequency of moulting and in the rate of development of these larvae has been briefly reviewed (Strickland 1933). To the data already presented can be added that two larvae pupated after the tenth instar, in which they were 20 millimeters and 17.5 millimeters long, respectively, while two which died when they measured 20 millimeters and 22 millimeters had already moulted 23 times.

It was suggested at the time that the extreme individual variation encountered among larvae which were kept under identical conditions might have been due, in large measure, to the very unnatural conditions under which these larvae, of necessity, were kept. In the field cages, however, in so far as can be judged from an annual inspection, variations are just as extreme as they are in the cans. In both instances the greatest variation in individual size occurs during the first two years. In the cans one individual shrank from 24 millimeters to 22 millimeters in 18 months despite the fact that it fed freely in the interval and moulted five times. There were few opportunities for

keeping track of individuals in the field cages, but a definite shrinkage of at least a millimeter between annual examinations was recorded on more than one occasion. One of the larvae in these cages reached the length of 17 millimeters by 1933 and did not vary in size at each subsequent examination till 1937, by which year it had pupated. We believe, therefore, that other individual variations which occurred in the cans are no more extreme than are those which maintain in the field. It is more than probable that we have not, as yet, observed the extremes of normal variation in any respect.

VARIATIONS IN LENGTH OF LIFE CYCLE.—A series of 42 field cages, such as are described above, was set out in a plot in a grain field at Edmonton in May, 1930. The soil which the cages contained was sterilized by heat in order to assure the destruction of any seeds which might be present. One reason for this procedure was that this experiment was designed also to yield data on the food requirements of the small larvae. Individual cages were seeded, in duplicate with the exception of the checks, with a variety of field crops and common weeds.

During June, as soon as larvae from eggs laid in captivity were available, each cage was stocked with 50 first-instar larvae.

Laboratory experiments had already shown that it was very difficult to recover first and second instar larvae even from small quantities of soil and that few individuals would have passed the second instar before winter. No attempt, therefore, was made to examine the large amount of root-entangled soil in these cages until the autumn of 1931. At each examination the soil, larvae and perennial growth, when this was under test, were returned to the cage, which was replaced in the field. Where annual plants were under test the cages were left unplanted till the following spring when, at the normal seeding date for the season, all, including the checks, were seeded with wheat.

Summer mortality was high and was increased in some years when seeding was somewhat delayed. It was evident that this was largely due to cannibalism since, in the years when a spring examination was made, several partially devoured (in one case still living) larvae were found. This must be a factor which produces an appreciable mortality among the less dense populations in the field, particularly in years of summer fallow. When, however, the population in any one cage was as low as two or three at the time of the first examination, subsequent mortality was very low.

Carabidae, especially in their larval stage, were responsible for the destruction of many wireworms in some of the cages. *Harpalus* spp. *Pterostichus* spp. and other small species destroyed wireworms of up to about 4 millimeters in length, but were rarely successful in attacking those which were larger. *Calosoma* spp., however, readily devoured all stages, including the adults.

Summarizing the results obtained in these cages, it was found that there was a very heavy mortality in all cages during the first two summers. This was undoubtedly due, to some extent, to the fact that, at that time, they contained the largest number of wireworms which thus had increased facilities for cannibalism. Despite this, the extreme drop in the population during the first two years can be attributed, chiefly, to the starvation of recently emerged larvae. Practically none had survived in those cages in which, during their first summer, they had been supplied only with dicotyledonous vegetation.

The following figures show the number of survivors at the end of each year between 1931 and 1938, together with the extremes in the length of the larvae and the individual length of adults. The larvae were measured as they crawled along the edge of a ruler.

1930.—2,100 first-instar larvae placed in the cages.

1931.—232 larvae. 3.5–14 mm.

1932.—135 larvae. 5–13 mm.

1933.—64 larvae. 9–20 mm. 2 adults. 2×9 mm.

1934.—37 larvae. 10–11 mm. 19 adults. 1×8 mm., 8×9 mm., 7×10 mm., 3×11 mm.

1935.—25 larvae. 11–20 mm. 4 adults. 3×9 mm., 1×11 mm.

1936.—18 larvae. 15–20 mm. 4 adults. 3×9 mm., 1×10 mm.

1937.—6 larvae. 16–22 mm. 10 adults. 1×8.5 mm., 2×9 mm., 4×10 mm., 2×11 mm., 1×13 mm.

1938.—No larvae. 6 adults. 5×9 mm., 1×13 mm.

In this field-cage experiment, therefore, the length of the larval life varied from three to eight years and, since the beetles would not have reproduced until the spring following that in which they were formed, the life cycle from four to nine years.

A second, rather larger, series was started in 1932. In this, the wireworms are developing with the same irregularity and at the same approximate rate. A four-year cycle appears to be the minimum, and, at the time of writing, it would appear that the nine-year cycle will not be exceeded.

From the above figures it is obvious that it will never be possible, from computing the size of maturing wireworms in a field, to deduce the factors which, in any given year, had a marked effect on the survival of eggs or newly emerged larvae, whether adversely or otherwise.

In those cages which were planted with perennial grasses the larvae increased in size more rapidly than did those larvae which fed exclusively on grain plants. The variation in size was most extreme during the first three years, after which the difference gradually disappeared. The number of years which were required for development appeared to be entirely unaffected by this initial variation in growth. That the extreme difference in the size of individuals of the same age is only partly due to the food available is shown by the amount of variation in a single cage. As an example we cite a cage seeded both in 1930 and in 1931 with wheat. The wireworms which it contained in October, 1931, were of the following lengths: 1×4.5 mm., 1×5 mm., 3×6.5 mm., 3×7 mm., 2×7.5 mm., 3×8 mm., 3×8.5 mm., 1×9 mm., 2×9.5 mm., 1×10 mm. and 1×12 mm. These, obviously, had rather more uniform opportunities for obtaining food and more similar conditions of moisture and temperature than would a scattered population in a wheatfield.

It will be noted that a prolonged developmental period did not, of necessity, produce a larger beetle. The majority of the beetles which required eight years to mature were only nine millimeters long and were of the same size as were those which matured in three years. In the second series of field cages a beetle which matured in three years measured 13 millimeters, and several which have matured at the end of the sixth year are only 9 millimeters in length.

Approximately the same number of each sex matured every year; of the two three-year old beetles one was a male and the other a female, and of the six eight-year olds two were males and four females.

FOOD REQUIREMENTS OF THE LARVAE.—As has been already stated, young unfed wireworms can be fairly readily starved whereas, once the third to fourth instars, in which the most advanced individuals pass their first winter, have been reached any attempt to destroy them by this means is impractical under field conditions.

Recently emerged larvae, if kept in damp soil, may die, apparently from starvation, after about eight days. The majority are dead at the end of three weeks, though a few will survive for as long as six weeks. Opportunities for cannibalism, in which they indulge freely, lengthen the duration of life, without access to suitable living vegetation, to about eight weeks. Some of these cannibalistic individuals reach the second instar. This is in marked contrast to the lengthy period which more mature wireworms can survive in the absence of vegetation.

It was apparent, also, that these recently hatched larvae can subsist on a relatively limited range of vegetation. As has been indicated earlier, it is extremely difficult to discover which of the diverse plants on which more mature wireworms will feed freely are the best suited to their needs when they can exist for a period of several years, and continue to grow, in the absence of all of them.

Recently emerged, unfed wire worms were offered a wide range of field crops and weeds in the three types of cages which have been described. Since the results in each type of cage were closely comparable with those obtained in the others it is unnecessary to consider them separately. In the majority of instances the vegetation was grown from seed and the wireworms were introduced as soon as plants were well established.

All experiments were conducted in duplicate. Many, including the field cage experiments, were repeated after an interval of two years.

The laboratory observation cages dem-

onstrated that newly emerged larvae will feed to some extent, and often very freely, on the rootlets or stems of practically every type of vegetation which is offered to them. When feeding on many plants they die at about the same time as do those to which no food has been offered. Signs that wireworms have fed is, therefore, no indication that they can survive on the particular type of vegetation on which they have been observed to feed.

In general, the larvae throve on all types of Gramineae though very few survived for long on any dicotyledonous plant.

In every instance, a fairly large percentage died, even when they had access to the most favorable type of vegetation. Death appeared to be due to starvation since a microscopical examination of the stomach showed it to be empty.

These laboratory observations were well substantiated by the field-cage experiments of which a more detailed account is given below.

For brevity, the results of the two separate field-cage experiments, which were started in 1930 and 1932 respectively, are combined.

Each cage was stocked, during June, with 50 recently emerged larvae bred from eggs laid in captivity. It was not examined for survivors until October of the following year. Unless the cage had been seeded to a perennial grass it was invariably seeded to wheat in the May of the year following the introduction of the larvae.

In the record of the number of recoveries the largest number found in any one cage only is given. Any variation between the duplicate or quadruplicate cages employed for each food plant, which appears to be significant in connection with the problem in hand, will be discussed.

CHECKS.—6 per cent survival.

Two field cages, which contained damp soil only in 1930, were stocked each with 50 larvae in June of that year. We were greatly surprised, when we examined them in October, 1931, to find that one contained three wireworms. During the second summer, in common with the rest of the series, these cages had been seeded with wheat.

Of some 550 larvae which had been employed in laboratory cages none had ever survived to beyond the second instar unless it had been given living vegetation.

Four check cages were employed in 1932. In none of these was there a survivor when an examination was made in October, 1933.

We are at loss to account for the presence of these three larvae. The complete mortality in all of the remaining checks indicates, however, that survival would be extremely low in a perfectly clean summer-fallow. Their presence throws some doubt on the probability that a dicotyledonous plant had served in any way to support life where one or two larvae were found in one only of the cages in which these food plants had been offered.

GERMINATING WHEAT.—30 per cent survival. 5.5–10.5 millimeters. Mean 8.6 millimeters long.

In a field, seeded at the normal time, little of this food would be available to the newly emerged larvae.

WHEAT PLANTS (about 4 inches high).—42 per cent survival. 4.5–12 millimeters. Mean 7.83 millimeters long.

Plants in about this stage of development would comprise the chief food supply in a wheat field. When the larvae are numerous they "notch" the roots from end to end, but the plants do not appear to suffer very greatly. Under laboratory conditions larvae survive in larger numbers on the germinating grain than they do on the roots. In the field, however, the roots of fairly well developed plants would be more readily found. We were unable to demonstrate any chemotropistic response which would direct the larvae to suitable food when they are in the soil.

GERMINATING OATS.—36 per cent survival. 6–9.5 millimeters. Mean 7.5 millimeters long.

OAT PLANTS.—26 per cent survival. 3.5–9.5 millimeters. Mean 6.8 millimeters long.

In the laboratory larvae are not so readily reared on oats as they are on wheat. Field observations indicated that wireworm populations tend to be higher in those fields, in any given district, in which wheat is grown frequently, than they are in those in which oats only have been raised. This may be due, in part, to the fact that oats are less favored as a food plant but may, also, be due to the

fact that this crop, frequently, is seeded two or three weeks later than wheat. This would, undoubtedly, increase the tendency to cannibalism where the former crop is grown.

BARLEY PLANTS.—34 per cent survival. 4–9 millimeters. Mean 6.1 millimeters long.

RYE PLANTS (spring seeded).—40 per cent survival. 4.5–12.5 millimeters. Mean 7.7 millimeters long.

WILD OAT PLANTS.—12 per cent survival. 6.5–8 millimeters. Mean 7.2 millimeters long.

(CORN).—Laboratory cages showed that this was a satisfactory source of food for the larvae. It was not tested in field-cages.

BROME GRASS (*Bromus inermis*).—72 per cent survival. 3–11 millimeters. Mean 6.9 millimeters long.

WESTERN RYE GRASS (*Agropyron tenerum*).—68 per cent survival. 4–11 millimeters. Mean 7.7 millimeters long.

CRESTED WHEAT GRASS (*Agropyron cristatum*).—62 per cent survival. 5–12 millimeters. Mean 8.6 millimeters long.

RED FESCUE (*Festuca rubra*).—50 per cent survival. 3–7 millimeters. Mean 4.8 millimeters long.

TIMOTHY (*Phleum pratense*).—46 per cent survival. 3–8 millimeters. Mean 5 millimeters long.

It will be noted that, though there was a fairly high percentage of survival in all grain crops, this was considerably higher in the cultivated fodder grasses.

In addition, although this is not well indicated in the series listed, in certain years young wireworms grow far more rapidly on the grasses than they do on grain crops.

In 1931, for instance, there was only a 42 per cent survival on Brome but the larvae averaged 10.5 millimeters in length. Similarly, a 14 per cent survival on Western Rye averaged 11.8 millimeters. During the same year wheat-fed larvae averaged only 7.83 millimeters. The difference in size was very evident at the time of examination. In each subsequent year it became less marked and, by the end of five years, had entirely disappeared. Furthermore, the early differences in size which resulted from the available food had no effect upon the number of years required for development, nor upon the size of the adult beetles. We believe that the difference in the rate of early growth is due, chiefly if not entirely, to the fact that the larvae are able to feed on a perennial grass from the day on which they resume activity in the spring and can continue so to do until their activity ceases in the autumn. In a grain field there is a period for potential feeding before the grain is seeded; by late summer the grain has ripened and no longer yields a food supply. This condition renders extensive feeding impossible at the two periods of greatest wireworm activity. The more mature larvae are so irregular in their feeding that lack of food in the grain field before seeding time and after harvest appears no longer to affect their rate of growth.

Timothy is, undoubtedly, a less satisfactory form of food for young wireworms than are other fodder crops. We had the greatest difficulty, in our laboratory cages, in keeping recently emerged larvae alive on this grass. They fed on it as freely as they did on brome, but the majority died about as quickly as did others which were allowed to feed only on dicotyledonous plants.

In the 1930–1931 series of field cages there was no survival on timothy, whereas 42 per cent survived on brome. However, in the 1932–1933 series, larvae survived in both timothy cages. As will be seen from the figures given above the survival was smaller than it was in the corresponding cages of brome and other plants, and the larvae were much smaller. In subsequent years the difference in size was evened up and the larvae are maturing to adults as rapidly on timothy as they are on other grasses.

Though the survival in our field-cages was low in red fescue, and the larvae were very small, we had no difficulty in keeping the larvae alive on this grass in our laboratory cages.

COUCH GRASS (*Agropyron repens*).—46 per cent survival. 3–12 millimeters. Mean 5.5 millimeters long.

BLUE-STEM (*Agropyron smithii*).—28 per cent survival. 4–9 millimeters. Mean 6.3 millimeters long.

BEARDED WHEAT GRASS (*Agropyron subsecundum*).—2 per cent survival. 4 millimeters long.

NEEDLE AND THREAD GRASS (*Stipa comata*).—14 per cent survival. 4–8 millimeters. Mean 6 millimeters long.

SPEAR GRASS (*Stipa sp.*).—26 per cent

survival. 5–10 millimeters. Mean 7.7 millimeters long.

It will be noted that the survival in these native grasses was, on the average, much lower than was that on the cultivated grasses. The seed which we obtained from several other native grasses, unfortunately, was not viable and experiments with these had to be abandoned.

FLAX.—10 per cent survival. A total of 5, 4, 4 and 0 larvae survived in the four cages employed in the two series of field-cage experiments. In the laboratory, recently emerged larvae fed freely, and some survived to the third instar, on seeds and seedlings of this crop. More mature larvae frequently are very destructive to flax in the field. It is, however, often recommended as an immune crop for seeding in badly infested districts.

ALFALFA.—4 per cent survival. Two larvae were found in one, only, of the cages.

SWEET CLOVER.—No survival.

SUNFLOWERS.—No survival.

(POTATOES).—Attempts to raise newly emerged larvae on potatoes in laboratory cages were unsuccessful. They fed freely on slices of the tubers but died at about the same time as did others which were not fed. No tests were conducted in field-cages.

These results indicate that, provided all grass and volunteer grain can be excluded, a moderately frequent insertion of a dicotyledonous field-crop in a rotation should, in time, have a beneficial effect in reducing wireworm populations. Unfortunately, flax appears to be the least suited for this purpose. The results also appear to have a direct bearing upon the problem of reducing the number of these wireworms in gardens. No attempt has been made to ascertain whether gardens which have been kept relatively free from grass for a number of years, and in which corn is never grown, suffer as seriously from these wireworms as do others. From rather casual observations around Edmonton, it would appear that they do not.

RUSSIAN PIGWEED (*Axyris amaranthoides*).—8 per cent survival. Both in the laboratory and in field cages it was found that there is an appreciable survival on this weed, on which recently emerged wireworms throve better than they did on any other dicotyledonous plant with the exception of flax.

WILD MUSTARD (*Sinapis arvensis*).—6 per cent survival. It has been suggested that cultivated mustard might be seeded in fields in order to reduce infestations by wireworms since they appeared to be less abundant in those fields in which the wild variety grew than they were elsewhere. In the laboratory, all stages fed freely on mustard with no observable deleterious effects. It would appear to be a more favorable food plant than are the majority of dicotyledonous weeds.

REDROOT PIGWEED (*Amaranthus retroflexus*).—4 per cent survival. Only two larvae survived in one of the four cages in which this weed was grown. In the laboratory, larvae feed very freely on seedlings but they did not survive.

TUMBLEWEED (*Amaranthus graecizans*).—Plants failed to make a sufficiently vigorous growth in our field-cages for us to feel that we had been able to make a fair test. There were no wireworm survivors. In the laboratory the extent of feeding and of larval life were similar to those obtained with redroot pigweed.

CANADA THISTLE (*Cirsium arvense*).—4 per cent survival.

TUMBLING MUSTARD (*Sisymbrium altissium*).—2 per cent survival.

LAMBSQUARTERS (*Chenopodium album*).—2 per cent survival.

RUSSIAN THISTLE (*Salsola pestifer*).—2 per cent survival.

There was a single living larva in one cage, only, of those cages which had been planted to each of the above three weeds.

BUCKWHEAT (*Bilderdykia Convolvulus*).—No survival.

WESTERN FALSE FLAX (*Camelina sativa*).—No survival.

SHEPHERD'S PURSE (*Capsella bursa-pastoris*).—No survival.

STINKWEED (*Thlaspi arvense*).—No survival.

PEPPERGRASS (*Lepidum sp.*).—No survival.

In the records of the survival in cages stocked with dicotyledonous plants, the length of the larvae is not given since, in all cases, they had fed during the second summer on wheat. Our object had been simply to discover whether, in the absence of a grain crop or a perennial grass they could support the life of newly emerged larvae in summer-fallow.

In addition to tests on the species recorded from field-cages, laboratory observations were made on ball mustard, hare's ear mustard, curled dock and yarrow. The larvae fed on all of these with the exception of hare's ear mustard but all of them died at about the same time as did unfed larvae in both types of breeding cages. When the experiment was ended three weeks after the last had died in these cages, there were survivors in all cages supplied with grains and grasses.

From these figures, incomplete as they are in connection with weeds which are apt to be encountered in summer-fallow, it is strongly suggested that the presence of dicotyledonous plants, with the possible exception of flax and Russian pigweed, is a relatively unimportant factor in determining the number of newly emerged larvae which will survive till the following year. It will be remembered that, in one of our check cages, there was a higher survival than there was in any of these cages except that containing wild mustard. A perfectly clean summer-fallow is probably the most certain method of assuring a very high percentage of mortality among these unfed larvae which have, at that time, as many as eight years of destructive activity ahead of them. It would appear, however, that, unless grains and grasses are fairly well represented in the vegetation which is present, a growth of other weeds is not a serious menace in this respect. The concentration of these highly cannibalistic larvae around a few scattered weeds in an otherwise clean fallow might, indeed, have a somewhat beneficial effect.

This is at variance with the findings of Lane (1931) in connection with the Great Basin wireworm, *Ludius pruininus noxius* (Hyslop). In order to assure the starvation of the newly emerged larvae of that species he specifies the destruction of Russian thistle, tumbling mustard and tumbleweed. It is assumed by King, Arnason & Glen (1933) that the findings of Lane apply, also, to the control of the species under consideration. The results of these experiments do not confirm this assumption. It is, however, obvious that the presence of grasses, such as couch, or a brome pasture which has not been completely destroyed, and of volunteer grain is a serious detriment to any attempt to reduce wireworm populations by starving newly emerged larvae by summer-fallowing, and that every effort should be made to destroy all traces of these before the middle of June.

SUMMARY.—Completed life cycle studies upon the northern grain wireworm, *Ludius aereipennis* (Kby.) var. *destructor* Brown, show that, in field cages in which conditions approximate those occurring in the field, the length of the life cycle and the rate at which the individual wireworms develop is very variable. The shortest period required for the completion of the life cycle was four years and the longest, nine years. The rate of growth, particularly during the first three years after hatching, is very erratic. In a typical cage, 15-month old larvae varied in length from 4.5 to 12 millimeters. These differences are reduced in subsequent years and a rapid early development is of no significance with regard to the number of years required for development, or to the ultimate size of the adult beetle. The number of larval instars varies from 10 to at least 24.

Newly emerged larvae die from starvation in a few weeks unless they have access to suitable living vegetation. More mature wireworms can live for at least three years in soil in which no vegetation is present. It is, therefore, impractical to attempt to starve wireworms in any year except that in which they have hatched. Monocotyledonous vegetation, alone, meets the requirements of these young larvae, though a small percentage may survive on a few dicotyledonous plants. These facts have a direct bearing on the problem of reducing wireworm populations by starving newly emerged larvae in summer-fallow.—9-13-38.

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The Yellow-Headed Spruce Sawfly in Maine

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The yellow-headed spruce sawfly, *Pikonema alaskensis* (Roh.), was first noticed in Maine at Readfield, near Augusta, in early July, 1934, where it was found feeding in a plantation of 5-foot high Norway spruce, *Picea excelsa*. During the past two years it has been found well over the state and in places abundantly. The interest in recent outbreaks of the European spruce sawfly, *Diprion polytomum* (Htg.), has caused numerous reports to be sent in of the former. H. B. Peirson, State Entomologist, was of great help in the work on this insect.

DISTRIBUTION.—This insect occurs from Alaska and British Columbia to Wyoming; east to Maine and New Brunswick. Other records listed by Ross (1938) are Alberta, Idaho, Saskatchewan, Manitoba, Michigan, Quebec. It has been recorded also from Massachusetts, Minnesota and New York. The first record known to the writer of its being found in eastern United States is from Forest Hills, Mass., on black spruce, *Picea mariana*, where larvae were taken in 1916 but no adults were obtained. Larvae were obtained in the same trees in July, 1917. Adults were reared from these larvae in May, 1918, which were identified as *Pachynematus piceae* Roh. These notes were supplied by John Schaffner of the New Haven, Conn., Forest Insects Laboratory, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. In late years, it has been common in eastern Canada as well as in Maine.

FOOD AND IMPORTANCE.—Larvae have been observed feeding in Maine on white spruce, *Picea glauca*, red spruce, *P. rubra*, and Norway spruce, *P. excelsa*. Other host trees recorded (Ross 1938) are black spruce, *P. mariana*, and Colorado blue spruce in Quebec; also Engelmann spruce, *P. engelmannii*, in British Columbia.

The new-growth foliage is definitely preferred. The late-stage larvae tend to spread about more and to feed on old needles even with new foliage still present, and with a scarcity of foliage may feed sometimes on the tender, outer tissues of the new growth stems. At present, the insect is a menace to young, open growth in plantations and natural reproductions. In many cases where such definitely favored trees have been found infested, nearby closed stands of spruce have been found to be uninfested.

A 20-acre plantation of Norway spruce and white pine 4 feet high has the spruce so severely injured that a sample of 100 trees counted in 1937 showed 40 dead, 41 defoliated 75 per cent or more, 9 defoliated less than 75 per cent and 10 with little or no defoliation.

Ornamental trees and a white spruce hedge completely defoliated have been seen. Light feeding on such trees causes them to appear noticeably ragged.

SYNONYMY.—Specimens were identified in 1936 as *Pachynematus alaskensis* Roh. by Grace Sandhouse of the U. S. Dept. of Agriculture. Since that time H. H. Ross (1937) of Urbana, Ill., has erected the genus *Pikonema* Ross. Ross (1938) says, " . . . reared from spruce many lots of sawfly larvae belonging to the *Pachynematus ocreatus* Hgtn. group, or 'group I' of Marlatt. These reared series have established . . . the correct association of the two sexes of the species and show that color is of little value in segregating the species . . . " He includes three species in the genus: (1) *Pikonema dimmockii* (Cresson) with the synonyms *Nematus dimmockii* Cresson and *N. ocreatus* Harrington; (2) *Pikonema ruralis* (Cresson) with the synonym *Nematus ruralis* Cresson; and (3) the species concerned in this paper *Pikonema alaskensis* (Rohwer)—the synonyms being *Pachynematus ocreatus* auct., nec Harrington, *P. alaskensis* Roh., and *P. piceae* Roh. Dr. Ross determined specimens sent by the writer as *Pikonema alaskensis* (Roh.).

The original description by S. A. Rohwer (1912) in 1911 was from three female specimens collected at Sitka, Alaska, in April, 1899, by T. Kincaid while on the Harriman Expedition.

DESCRIPTION.—The adult female sawflies vary somewhat in color. However, the general color of specimens seen by the writer is from straw to reddish-yellow with antennae, eyes, ocellar area and spots on body piceous or black, hind tarsi dark. Legs are long, the body from 8 millimeters to 10 millimeters long, slender

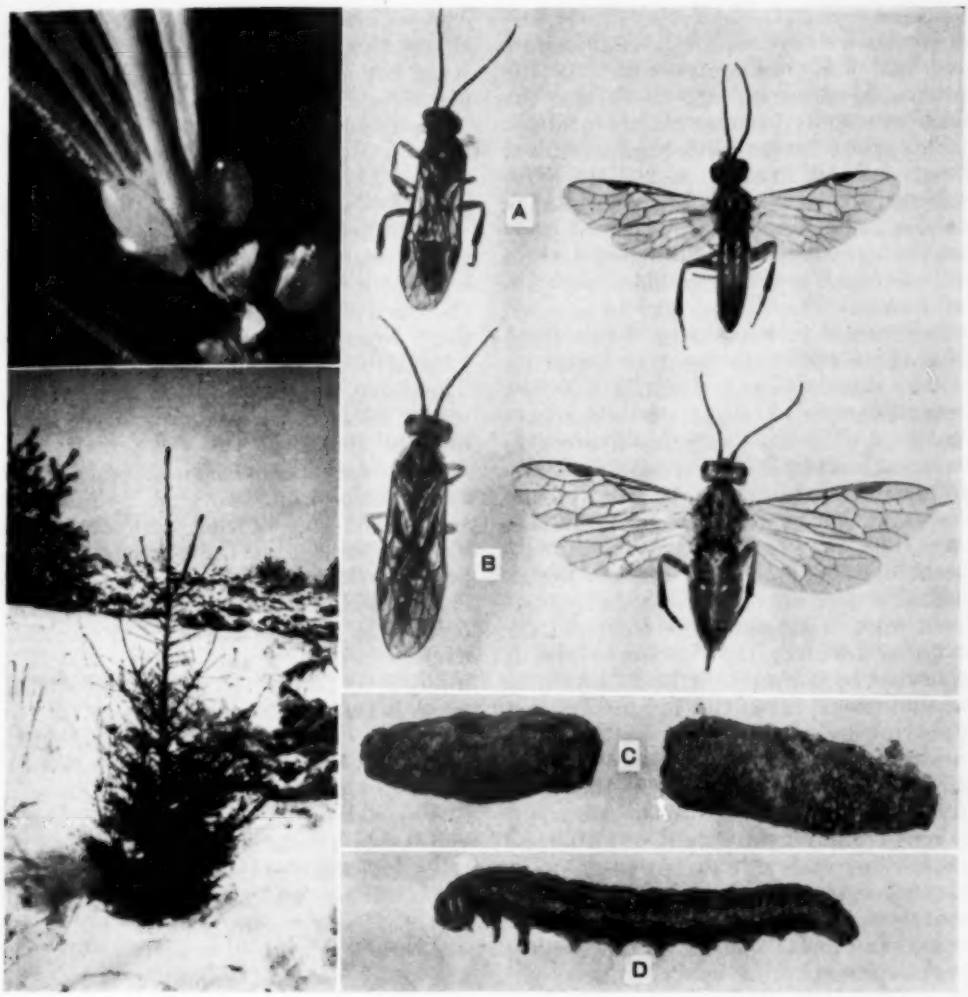

FIG. 1.—*Pikonema alaskensis* (Roh.). *A*, male and, *B*, female adults (×3). *C*, cocoons (×3)—male (left), female (right). *D*, full grown larva (×3). Upper left, eggs in bases of spruce needles (×9). Lower left, defoliation.

but enlarging at the abdomen. The insect has a wing-spread of about 19 millimeters. The sheath is shining, projects well beyond the cerci, and its apex has a fringe of fine setae. The distinctive feature of the sheath of this species is that it has an incision on the dorsal corner of the apex (Ross 1938). The saw terminates in a point.

My specimens of males show the body and hind tarsi black, with rest of the legs straw to reddish-yellow with a dark hue and with black spots at bases. Three and sometimes four consecutive abdominal segments are of a dark reddish-yellow color and give a definite band to the body coloration. Males are about 8 millimeters long, with the body more slender than that of female but of a consistent width, fig. 1.

One must bear in mind the statements by Ross (1938) on color of which he says, "A series of 40 females indicates that the color of the abdomen is usually chestnut with occasional dark suffusions at the base, but varies to entirely black. The male seems to have the abdomen always banded with rufous. The narrowness of this band in some specimens may indicate that sometimes the abdomen is entirely black in this sex also."

The pearly-white egg is ovate and has

the thin, colorless shell very finely stipuled. Its average size is 1.3 millimeters long and 0.67 millimeter wide. As the embryo develops the egg swells and the black eye spots become plainly evident.

Full grown larvae have head widths of about 1.9 millimeters and 1.72 millimeters, respectively, for those producing females and males, the respective body lengths averaging 20 millimeters and 16 millimeters. They have a dark reddish-yellow head which often may be mottled with brown of various shades. Ross (1938) gives the color of the head as "chestnut brown, sometimes with a mottling of dark brown over the chestnut, and sometimes almost black." Eyes vary from brown to black with a black area around the base. Antennae brown, located in front of and closer together than eyes. Ends of mouthparts dark brown. Body dark yellowish-green, underside of body lighter. Longitudinal stripes and spots of a dirty gray-green color occur along the length of the body as follows: (1) A double stripe, separated by a narrow lighter line, along the mid-dorsal area; the lighter line disappearing and the double stripe becoming one toward the caudal end of the body; (2) a stripe along each side of the back, more or less broken into a double stripe by an irregular lighter area; (3) a lateral stripe along each side except the last abdominal segment—this stripe being somewhat irregularly interrupted by lighter areas; (4) a linear spot on all but the last three segments, this spot being on the outer side of the fleshy area by the base of each thoracic leg and proleg. Thoracic legs are shaded with dark areas. They extend well out to the side of the larva when crawling. Prolegs are the color of the body and are present on all but the first, eighth and ninth abdominal segments. Setae occur scattered over the head, sparingly over the body and legs with small groups on the ventral parts of segments where prolegs are lacking and a thick group above and below the anal opening. The apical tergite is round.

The newly hatched larva is about 3.5 millimeters long with a head width of 0.57 millimeters. The head and body are very light yellow, eyes black, and antennae and ends of mandibles brown. Shortly after feeding begins the head becomes light orange-yellow, the slender body and prolegs light yellow green. No stripes occur on the body. The intestinal tract shows through as green. In the second stage the colors deepen slightly, the eye disks vary from light to dark-brown and the area around the base of each eye is black. In this stage the darker stripes described above begin to appear; however, only the lateral stripes and the fore part of the other stripes are conspicuous. Dark spots occur on the underside between the legs of the first two thoracic segments. In the third stage the stripes are plainly evident. From this stage on the stripes and general body and head coloring deepen. The setae described above occur in all stages, becoming larger with the development of the larva.

The prepupa appears the same as the larva—coloration being the same and setae remaining of the same size. After the cocoon is spun, the segments are appressed to each other so that the insect is much contracted to about 8.5 millimeters in length. The head widths average about 2 millimeters and 1.75 millimeters for those prepupae producing females and males respectively.

The cocoon is thin, slightly tough, dark brown, rather rough and occasionally fibrous, with granules of soil sticking to the fibers and to the cocoon itself. One end is blunt, round and larger than the other end which tapers to a blunt point; the latter being closed only by a mass of threads loose on the exterior but fairly well stuck together inwardly. Cocoons are glazed inside. Some are straight, others slightly curved. They are spun beneath infested trees in the mineral soil to a depth of about an inch. The size varies from 10×3.5 millimeters to 14×5 millimeters. There are two general sizes; those from which females emerge will average roughly 12.5×4.5 millimeters, male cocoons will average 10.75×3.75 millimeters. The writer has had fair results in separating the two before adult emergence; however, there are intergradations. The prepupa is considerably smaller than the cocoon.

The pupa is at first light cream color, gradually assuming the darker colorations of the adult.

The circular emergence hole is cut by the adult at the larger end of the cocoon.

LIFE HISTORY.—Adults emerge, crawl to a free place at the surface of the ground, immediately spread and beat

their wings two or three times and then take flight. Emergence occurs in the Augusta area the last of May. Adults are found freely ovipositing then and the first of June when the new growth is about 1 inch in length. In 1937, unhatched eggs were found as late as June 14. In northern Maine, adults have been found flying on June 21. They are moderate flyers, especially the females. Observations in infested plantations indicate that they do not tend to spread about readily to areas away from trees beneath which they have developed. They are most active on warm, sunny days.

Eggs are laid in shallow slits on the outer part of new-growth needles usually at the base, but occasionally farther up on the needle or even in the stem part of the new growth. The small slits run lengthwise of the needle and flange out at the margin so as to receive the egg which is well exposed. Only the bottom (about one-fifth of the total egg surface) is inserted in the slit. One egg, well stuck on, is laid on each slit and thus far only one per needle has been found.

Eggs hatch in from six to eight days. At first the larvae eat small areas out of the new needles but later devour the entire needle. The feeding period lasts from 30 to 40 days. The larva lays along the needle with the caudal end curled around it. When disturbed it exudes a liquid from the mouth and whips and arches the caudal end.

The prepupae drop from the trees, go into the ground, and spin the cocoons. Cocoon spinning begins the first week in July—in 1937 the first record was July 3—and continues into the last half of the month. Pupation does not occur until the coming of warm weather in the following spring. The length of the pupal stage is difficult to determine but in one definite case it occupied six days at a temperature of 74 degrees F.

COMPARISON WITH *Diprion Polytomum*.—In the extensive surveys for feeding, and presence of cocoons, of the European spruce sawfly, *Diprion polytomum*, in Maine, persons often confuse the insect with *Pikonema alaskensis*. The two may be separated easily. Larvae of the European species feed preferably on old foliage, and appear as follows: Head of a tan color with brown markings; body of a color resembling that of the spruce foliage and having five longitudinal white stripes in the fourth and fifth stages. The cocoons are smooth, shiny and ovoid so that both ends are similar in shape. In addition, the adults are black with yellow markings; the body is stout appearing, antennae are short and males are rare in this country.

PARASITIC INSECTS.—At Weeks Mills near Augusta, sawfly eggs of a jet black color were observed. Since parasitism was suspected, such eggs were caged on June 4, 1937, and on June 14, 16 minute Chalcids emerged, later to be determined as *Trichogramma minutum* Riley by P. Dowden of the New Haven, Conn., Forest Insect Laboratory, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine. Other eggs caged on June 17 yielded these parasites until June 25. About 1 per cent of the eggs was parasitized. Three such eggs were constricted about the middle to give them the appearance of a double egg. Only one parasite emerged from each egg. However, one constricted egg was noted as having the regular emergence hole of a parasite, but instead of being empty it contained a dried parasite pupa.

The Tachinid, *Bessa selecta* (Mg.), determined also by P. Dowden, parasitized the sawfly larvae in 1934 at Readfield. Of 40 nearly full grown larvae caged July 8 to rear adults, all but two were parasitized by this species. Maggots of the parasite deserted the killed sawfly larvae and pupated on July 15 and emerged as adult flies July 18 and 19. The sawfly infestation, however, was practically as severe in 1935. About 100 larvae were caged in 1937, but only one specimen of this species was obtained.

Development of the sawfly was forced by bringing caged cocoons from Readfield indoors to a temperature of 74 degrees F. in February, 1938. From 16 per cent of these cocoons, 3 species of Hymenopterous parasites emerged. R. A. Cushman of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, Washington, D. C., determined one species as *Monoblastus* sp. C. F. W. Muesebeck of the same Bureau found the other specimens to represent two species of the genus *Ichneutes*—(1) possibly *I. fulvipes* Cress. and (2) in all probability a new species.

Through 1937 the Readfield infestation has held fairly constant and seemingly

has lessened very slightly since found in 1934.

No predators were observed.

CONTROL ON ORNAMENTAL SPRUCE.—Control on shade and ornamental trees consists of spraying with lead arsenate at the rate of 4 pounds to 100 gallons of water, plus 4 ounces by weight of linseed oil or fish oil for each pound of lead arsenate used. The spray should be applied when the larvae are young—about the first week in June at Augusta.

Nicotine sulfate—one part to 600 parts of water plus one-half ounce of soap well dissolved for each gallon of spray, applied in the Augusta region the end of the first week in June—can be recommended for control. It is more expensive but is preferred by some to lead arsenate for spraying trees close to houses where children and pets are present. The new growth of spruce should be examined closely the first of June. When the small, light colored larvae are present the trees should be sprayed. After the larvae reach the third instar this insecticide is not practical to use as, even at a dilution of 1–400, many of the larvae are merely stunned for a brief time.

CONTROL IN FOREST GROWTH.—More work is needed to determine the possible value of parasitic insects in checking this sawfly in forested areas. Since infestations observed for four years have remained in the same general parts of plantations each year, indications are that one thorough spraying with lead arsenate for a serious infestation in valuable young plantations would be sufficient to check the insect for several years. This would give the trees a chance to acquire growth and height and thus enable them to withstand much more severe infestations. From the few observations which we have to date, the main danger of serious injury and death is with small trees up to 6 feet in height. No stands have been observed where infestations were just beginning; hence it is not known how quickly a severe infestation will build up.—9-16-38.

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Sedimentation and Microprojection Methods for Determining Particle-Size Distribution of Insecticidal Materials

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The particle-size distribution of numerous samples of Paris green (Goodhue & Gooden 1937), calcium arsenate (Goodhue 1937), and sulfur (Goodhue 1938) as determined by sedimentation analysis has been reported in previous papers. Although based on sound principles of physics and mathematics, this method is an indirect one and the results may be looked upon with suspicion by those not familiar with the procedure. Results obtained by measurement under the microscope may be more readily accepted, because this is a direct method that approaches more nearly the familiar method of determining the size of larger objects.

A comparison of results by sedimentation analysis with those by some microscopic method has been made by Bishop (1934), using glass spheres and by Jones (1938) using fractions of an abrasive. In neither case did the two methods check very closely, although fair agreement was obtained.

In this investigation three samples of sulfur found by sedimentation to vary greatly were also subjected to particle-size analysis by a microscopic method, and the results obtained by the two methods were compared.

SEDIMENTATION APPARATUS AND PROCEDURE.—The sedimentation analyses

were carried out essentially according to the method of Goodhue & Smith (1936). The original apparatus was improved by substitution of a capillary (2-millimeter bore) for one of the stopcocks. The improved apparatus (fig. 1) had the following dimensions: The sedimentation tube (*1*) was 20 inches long and 1½ inches in diameter. The small tube (*2*) was 7 inches long and five-eighths inch in diameter. The 3-millimeter bore manometer tube (*3*) was attached through the L-shaped stopcock (*4*) to the upper tube (*2*) about 3 inches from the top of the apparatus and again through the tapered capillary (*5*) to the large tube (*1*) about 4 inches from the bottom of the apparatus. The upper part of the manometer tube was provided with a paper scale (*7*), held in place by a jacket (*10*). The stopcock had a 10-millimeter horizontal arm to prevent the entrapment of air bubbles during filling. The manometer tube was 7 millimeters in outside diameter. The capillary at (*5*) was blown out to about three-eighths inch in diameter where it was joined to the sedimentation tube, but it was made to taper sharply to one-tenth inch before it opened into the manometer tube. This shape prevented bubbles from entering the tube (*3*) during the filling of the apparatus.

The suspension was stirred with a long-handled brush as described in the original article, but the filling and stirring may be further facilitated by the arrangement shown at the right in fig. 1. This combination funnel and stirring apparatus consists of a long-stemmed metal funnel having four small holes (*13*) in the sides of the stem (*12*) near the bottom. The stem is closed at the bottom and rigidly attached to a wire (*14*) carrying a section of a brush (*15*) at the lower end. This device is not removed from the apparatus during the analysis.

The temperature was maintained near 30 degrees C. constant to ± 0.05 degrees by immersion in a controlled water bath. The sedimentation was followed for 21 hours, which is the time required to obtain a value on the particles having a diameter of 4 microns. The results, shown in table 1 and fig. 2, were calculated essentially by the familiar method of Odén (1926).

MICROPROJECTION APPARATUS AND PROCEDURE.—The microprojection apparatus was a simple assembly of commercially available parts, with the exception of the two projection screens.

The screens were of rough-surfaced white cardboard, each hand-ruled, with a network of squares for reading particle diameters directly in microns. The screen used in most of the observations was

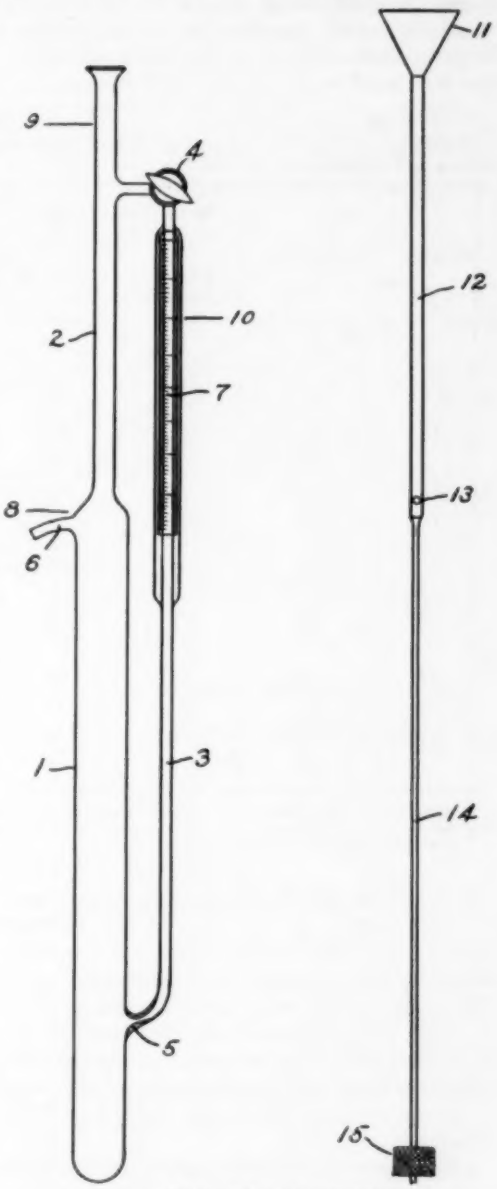

FIG. 1.—Sedimentation apparatus.

ruled for a magnification of 1,250 diameters; the other screen, which was used for the largest particles, was ruled for 90 diameters. (In a few cases it was found

convenient to use gauges, drawn on slips of cardboard, held against the screen to determine the image sizes; but this is a minor detail.)

The microscope was equipped with a 20× projection eyepiece to which was attached a totally reflecting prism. For the higher magnification, a 45× dry objective was employed; for the lower magnification, a 3.2× objective. The substage mirror was used to direct the light beam into the microscope, the lamp being situated several inches to one side of the microscope, and the microscope and screen both being used in a vertical position. The microscope was near enough to the screen (approximately 1 foot away) to make possible easy viewing of the screen and simultaneous manipulation of the mechanical stage without any remote control device.

The light source was a 32-candlepower automobile headlight lamp, mounted in an ordinary focusing microscope lamp housing, having a condenser with an iris diaphragm. This type of lamp, being inexpensive, was economically operated at approximately 10 volts instead of the 6 to 8 volts for which it is rated, thereby giving a brighter field at the higher magnification than is obtainable under the same conditions with ribbon filament lamps, which because of their expensiveness are not feasible to operate above the voltage for which they are rated. The voltage used for these observations was obtained from the house line by the use of a variable transformer, and to avoid undue shock to the filament the current was turned on and off by means of the voltage control instead of the switch.

The focusing of the incident beam was done by the usual methods.

The sulfur was incorporated in the same fluid mixture and dispersed in the same way as for the sedimentation method (Goodhue & Smith 1936). A drop of the sulfur-bearing liquid was then placed on a microscope slide and covered with a glass. Fields were observed at regular intervals, a dozen or more fields to the slide when the lower magnification was employed and at least a hundred fields to the slide when the higher magnification was used. In the latter case the finest particles were not counted in every field,

Table 1.—Comparison of particle-size distribution in samples of sulfur as determined by sedimentation and by microprojection.

Sample	Trial	Percentage (by Weight) of Particles of Indicated Range in Diameter*					
		0 to 10 Microns	10 to 20 Microns	20 to 30 Microns	30 to 40 Microns	40 to 60 Microns	Greater Than 60 Microns
Sedimentation							
I	A	73	22	1	1	—†	—†
II	A	27	33	15	5	15	5
	B	30	32	16	4	13	5
III	A	6	9	23	15	34	13
	B	7	11	25	19	30	8
Microprojection							
I	A	83	9	5	3	0	0
	B	74	18	5	3	0	0
II	A	32	34	20	11	2	1
	B	27	24	22	16	10	1
III	A	5	10	19	20	17	29
	B	2	10	18	21	20	29

* In practice the size ranges were often much narrower than those indicated in the table, which is condensed to facilitate comparison.

† 1 per cent greater than 40 microns.

but only in enough fields to obtain a good statistical average. Both magnifications were used on each sample, 90× for the coarser and 1,250× for the finer particles. The particles were hastily examined one by one, the observer estimating for each particle its average or effective diameter within certain appropriate limits, from 1 to 25 microns apart, depending on the size of the particle. The size-group classification of each particle was tallied either mechanically or by an assistant. Two slides from each sample were examined.

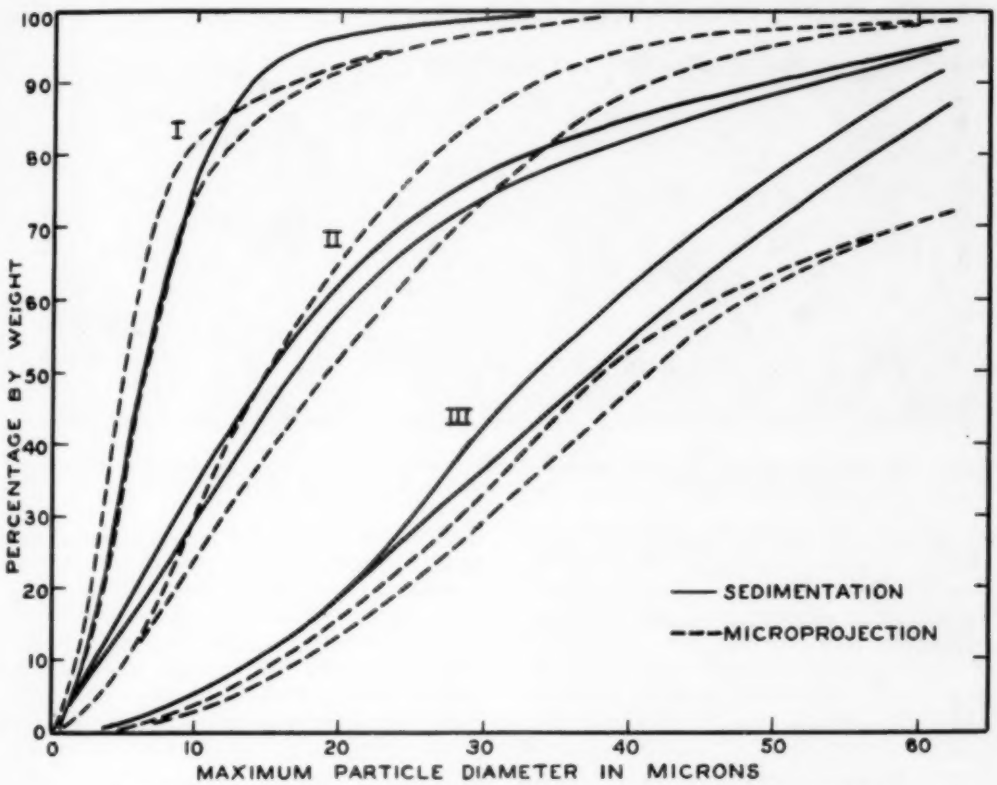

FIG. 2.—Particle size distribution in sulfur samples as indicated by sedimentation and by microprojection.

From the tabulated counts were plotted cumulative number-frequency curves, from which was deduced the probable number of particles of each possible size in steps of 1 micron of diameter. These results were converted into cumulative weight-percentage curves.

DISCUSSION OF METHODS AND RESULTS.—The determination of the exact size of very fine particles with the degree of accuracy obtainable in the measurement of larger objects is practically impossible by any method. There are several reasons for this. If a microscopic method is used, the projection of an irregular particle shows an infinite number of diameters all in the same plane, any one of which may be greatly different from any logical average diameter of the solid, because the third dimension, which is likely to be relatively small, does not appear in the projection. If a very fine powder is mounted in a liquid, the apparent diameter depends greatly on the refractive index of the medium chosen, a variation up to 20 per cent being indicated in some published observations (Bishop 1934); if mounted dry, the powder is not well dispersed. If the measurements are made indirectly by a method such as sedimentation, a value is obtained approaching the average diameter of an irregular particle or, to be exact, of a sphere with the same falling velocity. Since even under

the best conditions a true value of size cannot be obtained, the choice of methods should depend on the uniformity of the material and the practicability of the method.

With a material of uniform density, such as most insecticides, the sedimentation method has many advantages. The working time required to obtain a good result is much less; the chance of getting a uniform sample is better, and no personal element enters. Since a large number of particles is taken, a statistically good number is always obtained with both the very fine and the very coarse particles. Moreover, a sedimentation gives the percentage of very fine particles the outlines of which are not visible even under the microscope. The time required to determine the particle size distribution of a sample of sulfur by sedimentation is 20 hours, but this is mostly in the overnight period, only about 2 hours' actual working time being necessary to run three samples simultaneously.

By microprojection the time varies with the degree of accuracy required. For a good statistical result from 7 to 10 hours are required for one sample. The working time is considerably prolonged by the necessity for frequent rest periods to avoid eyestrain and in many cases for repeating with a different magnification. The time required to calculate the results is considerably longer for microprojection than for sedimentation, especially if wieght distribution is required. Both in the observations and in the calculations it is necessary to cover in detail the entire range of particle sizes occurring in the sample, even though the purposes of the determination may call for only a certain portion of the distribution curve; in this respect also the microprojection method is at a disadvantage.

The degree of precision obtainable by the two methods is indicated in fig. 2 and table 1. This is about equal to that obtained by Bishop (1934) and by Jones (1938). Since a number distribution is obtained in one case and a weight distribution in the other, for a comparison the results of one must be converted. In the experiment reported here the number distribution obtained by microprojection was converted to weight distribution and compared with the weight-distribution curves obtained directly by sedimentation. Although there is considerable variation within each sample, it is easy to see that three distinct samples are represented.

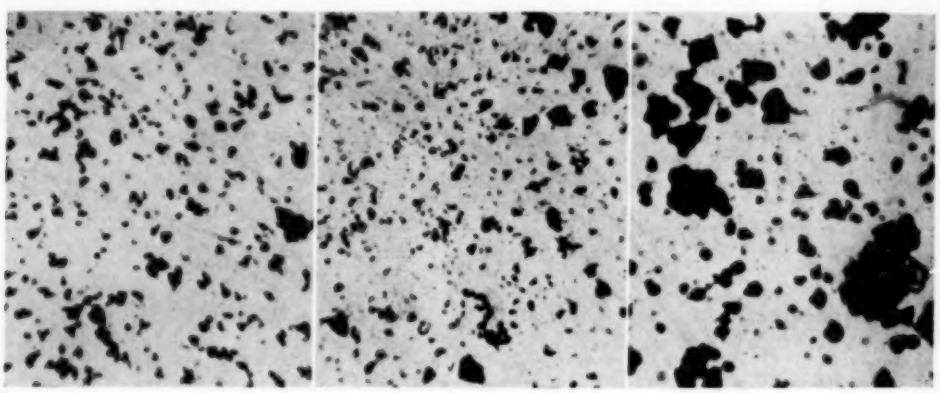

FIG. 3.—Photomicrographs of the three samples of sulfur used for comparison of particle-size distribution as determined by sedimentation and by microprojection. Left, I; center, II; right, III (×100)

The photographs in fig. 3 help one to visualize the difference in particle size; the difference between I and II, however, is shown better by the curves.

SUMMARY.—The particle-size distribution of three commercial samples of sulfur has been determined by sedimentation and by microprojection. As far as precision is concerned there is probably no choice between the methods, but the comparative ease with which results can be obtained by sedimentation should give this method preference for most insecticidal materials. Improvements in apparatus for both methods are described. —9-23-38.

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The Development of Immunity in Cavies to the Larvae of *Cochliomyia americana* C & P.*

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The economic importance of myiasis in domestic animals fully justifies more research aimed at methods of control which would give greater projection to animals than those now employed. The study of immunity to myiasis has received little attention in spite of the fact that if it were feasible to induce a relatively long-lasting immunity to this malady in livestock it would be a distinct advance toward the solution of this problem.

Borgstrom (1938) has recently published the results of her experiments to determine the nature and degree of immunity produced by an initial sublethal infestation of the screwworm, *Cochliomyia americana* C. & P. in cavies. She found that (1) an immunity to the effects of reinfestations with *C. americana* was developed, but the immunity was local and of short duration; (2) there was a reduction in the number of larvae which succeeded in establishing themselves when placed in a prevously infested animal; (3) a single species of bacillus, *Proteus chandleri*, sp. n., was invariably assocated with lesions infested with *C. americana* larvae; (4) the exudates from wounds infested with *C. americana* larvae contained immunizing properties; (5) the bacteria apparently played no role in the production of immunity; and (6) subcutaneous injections of suspensions of dried larvae produced only a delay of several days in the death of animals subsequently infested in the same areas with a lethal number of larvae.

At the Dallas, Tex., station of the Bureau of Entomology and Plant Quarantine some experiments have been conducted during the past year to determine the degree of immunity produced in cavies by initial maximum sublethal infestations of *Cochliomyia americana*. Experiments were also conducted for studying the development of generalized immunity, the inheritance of immunity and the immunizing effect of vaccines prepared from tub-reared *C. americana* larvae and from pure cultures of *P. chandleri*. In all cases the immunity or tolerance produced was determined by the reaction to subsequent infestations with supposedly lethal numbers of larvae.

METHOD OF INFESTATION.—All the cavies used in the experiments were secured from one source, and as a whole were quite uniform in age and size for the initial infestation. Young first-stage larvae which hatched on wet filter paper in Petri dishes containing a small amount of finely ground lean beef were used in all experiments. The newly hatched larvae fed readily on the finely ground beef, and they remained in excellent condition in the Petri dishes for at least 12 hours. By

* Early publication of this paper has been secured by payment of the printing charge.

the aid of a low-power dissecting microscope the desired number of young larvae were transferred, one by one, from the Petri dish to the wound. In all tests, except when the development of generalized immunity was studied, the implantation was made in an artificial horizontal wound approximately three-quarters of an inch long and centered about 1 inch behind the right scapula. Generally a safety razor blade was used for wounding the animal, and extreme care was exercised to secure wounds of the same dimensions in all animals. No larvae were implanted until the wound had ceased bleeding and the accumulated blood had been removed. For 24 hours the young larvae were protected and held in the wound by a moist cotton pad, gently but securely held in place by adhesive tape encircling the body of the animal. The infested animals were kept in cages until the fourth myiatic day, when they were placed individually in a no. 2 metal tub containing food, drink and a bedding of leaf prairie hay. This tub and bedding served admirably to protect and retain the mature larvae when they left the wound and to assure recovery of the exact number of larvae that completed development. No reinfestations were attempted until the animal had apparently fully recuperated from the last previous infestation.

A MAXIMUM SUBLETHAL AND A MINIMUM LETHAL INITIAL INFESTATION.—The results of numerous tests with cavies showed a considerable variation among different individuals in the number of larvae which constitute an initial maximum sublethal infestation when infested as described. This is true, regardless of the fact that the external characteristics of the animals may be remarkably similar. It was found, however, that the average maximum sublethal initial infestation was two larvae per hectogram of body weight. Only one animal in approximately 50 succumbed to an initial infestation of this proportion. When as many as three larvae per hectogram of body weight actually develop in an initial infestation of a cavy, death nearly always follows. Some cavies are exceptions to this rule but their number in the aggregate is low, and the reason for their greater tolerance to initial infestations is unknown. On the basis of nearly 200 records it may be stated that two larvae per hectogram of body weight constitute a maximum sublethal infestation, and three larvae per hectogram of body weight a minimum lethal initial infestation of *Cochliomyia americana* in the average cavy.

DEGREE OF IMMUNITY PRODUCED BY INITIAL SUBLETHAL INFESTATIONS.—The degree of immunity or tolerance produced by initial sublethal infestations was determined by the reaction to reinfestations with supposedly lethal numbers (three or more) of larvae per hectogram of body weight. More than 100 cavies, including the controls, were used in these tests. Animals which survived the first reinfestation were subsequently used for second and third reinfestations. These multiple reinfestations provided an opportunity to determine whether immunity is enhanced with repeated reinfestations. The results of these tests showed that only one animal in 68 failed to survive one to three reinfestations of three larvae per hectogram of body weight—a lethal initial infestation. Approximately 90 per cent of all reinfested animals were able to survive three and a half larvae per hectogram of body weight, but only a few cavies were able to survive four larvae per hectogram of body weight. The maximum number tolerated by any animal was 4.05 larvae per hectogram of body weight for either one or as many as three reinfestations. These results indicate that reinfestations do not enhance immunity or tolerance in cavies above that developed from an initial infestation and that the degree of tolerance so developed is approximately from 50 to 100 per cent greater than that of animals which had not been infested previously. The initial maximum sublethal infestation always caused a loss of appetite, severe emaciation and weakness and usually abortion; whereas on reinfestations, even with a greater number of larvae, these symptoms were far less severe. Records on the development of nearly 3,000 larvae implanted in wounds of cavies showed a development of 82 per cent of larvae from initial infestations, 79.7 per cent from first reinfestations, 80.6 per cent from second reinfestations and 90.2 per cent from third reinfestations. Since there exists no significant difference in these records it is rather conclusive that no substances deleterious to the larvae were developed by cavies from initial infestation or

from as many as three reinfestations of *Cochliomyia americana*.

THE DEVELOPMENT OF A DEGREE OF GENERALIZED IMMUNITY.—Two lots of six animals each were used in this test. Lot 1 had survived an initial infestation implanted 65 days previously and lot 2 had survived an initial infestation 109 days, and a reinfestation 65 days, previously. In this experiment both lots of animals received four larvae per hectogram of body weight in a wound of the described type, but located behind the left scapula, or on the opposite side of the body from the site of the previous infestations. With one exception, more than three larvae per hectogram of body weight completed development in every animal. Three of the animals in lot 1 and five of those in lot 2 survived the infestation. Since the larvae which developed in each of the surviving animals constituted an initial lethal number it seems probable that the tolerance manifested by the surviving animals was developed by previous infestations on the opposite side of the body, indicating either an extension of a local immunity or the development of a systemic immunity.

INHERITANCE OF IMMUNITY.—During the course of the experiments several cavies were born of infested parents. Six of these were tested for a possible inheritance of immunity or tolerance by a comparison with six control animals. Standard wounds identically located in all animals were infested with four larvae per hectogram of body weight. The number of larvae that developed in cavies from infested parents ranged from 2.44 to 3.87, with an average of 3.15, per hectogram of body weight; whereas in the six control animals the variation ranged from 2.43 to 4.00, with an average of 3.43. Death resulted in all six animals from infested parents and in five of the controls. Based on the results with this small number of animals, it is indicated that no immunity or enhanced tolerance to *Cochliomyia americana* is inherited by cavies born of infested parents. It is of interest to note that one of the control animals in this experiment survived an initial infestation of four larvae per hectogram of body weight. So great an initial infestation is rarely tolerated, and the reason for it is unknown.

THE IMMUNIZING PROPERTIES OF *Cochliomyia americana* AND *Proteus chandleri*.—In this experiment 12 cavies were divided into three lots of four animals each. Lot 1 was injected with a sterile suspension of mature tub-reared *Cochliomyia americana* larvae; lot 2 was injected with a sterile suspension of a pure culture of *Proteus chandleri;* and lot 3 served as a control. Two subcutaneous injections in all animals in lots 1 and 2 were made in the right foreflank, each animal receiving 1 cubic centimeter of the designated suspension for the first dose and 1½ cubic centimeters, 3 days later, for the second dose. The usual method of administering an initial minimum lethal infestation with young *C. americana* larvae was followed three days after the last injection of the suspensions in question. The results of this experiment show no surviving animals. The average number of days required for the infestation to produce death of all animals in the control lot, the lot receiving a *C. americana* suspension, and the lot receiving a suspension of *P. chandleri* was 7.5, 13.5 and 17.5, respectively. Although the number of animals and the number of injections in the test were small and the period perhaps too short for the development of maximum immunity, the results obtained confirm those of Borgstrom and indicate that, other than a slight retardation of death, no greater tolerance to *C. americana* than that occurring in normal cavies was produced by injections of sterile suspensions of mature *C. americana* larvae and *P. chandleri*. Since Borgstrom also injected active cultures of *P. chandleri* with no different results, it would appear that the immunity or enhanced tolerance produced in cavies by an active infestation of *C. americana* is due to the metabolic products of the larvae.

SUMMARY.—The number of *Cochliomyia americana* C. & P. larvae constituting a maximum sublethal and a minimum lethal initial infestation in the average cavy was found to be two and three, respectively, per hectogram of body weight.

The immunity or enhanced tolerance developed in cavies to *Cochliomyia americana* larvae from initial maximum sublethal and from three reinfestations was determined. The amount so developed is approximately 50 to 100 per cent greater than that of uninfested animals and is the result of the initial infestation.

No substances deleterious to the larvae were developed by cavies from initial infestations or by as many as three reinfestations.

In cavies either the extension of a local immunity or the establishing of a systemic immunity by previous infestations of screwworms was demonstrated.

On the basis of a small number of animals tested, it is indicated that no enhanced tolerance to *Cochliomyia americana* is inherited by cavies born of infested parents.

Other than a slight retardation of death, no tolerance to *Cochliomyia americana* greater than that occurring in normal cavies was produced by injections of sterile suspensions of mature tub-reared *C. americana* larvae and of *Proteus chandleri*.—3-13-39.

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SCIENTIFIC NOTES

Micromyzus oliveri Essig as a Greenhouse Pest

Late in the fall of 1936 dark reddish-brown aphids were noted on potted ornamental *Allium* in the laboratory greenhouse at Sumner, Wash. Alate

FIG. 1.—Colony of *Micromyzus oliveri* on flower umbel of greenhouse-grown *Allium recurvatum superbum*.

forms were present, and specimens were determined by P. W. Mason as *Micromyzus oliveri* Essig. As far as we know there is only one published record of this species, namely, the original description by Essig (1935) in which the aphid is reported as having been collected on *Calendula officinalis* at Clovis, Fresno County, Calif., on March 30, 1935, by S. J. Oliver.

The greenhouse infestation at Sumner was allowed to develop without hindrance except when the aphids attacked certain experimental plants. They were easily eliminated from these plants by the use of a spray consisting of 1 part of nicotine sulfate solution (containing 40 per cent of nicotine by weight) to 800 parts of water by volume, plus soap at the rate of 1 ounce per gallon. During April and May and early in June in 1937 the infestations dwin-

FIG. 2.—Infestation of *Micromyzus oliveri* on potted onion (*Allium cepa*) in greenhouse.

dled gradually until by the middle of June the aphids had apparently disappeared. Late in August, however, sparse colonies were noted developing on *Lilium longiflorum* and on ornamental *Allium*, all

individuals being apterous. Reproduction in these colonies was slow until October and November, when it became more rapid. During this time infestation was noted on chickweed growing under the greenhouse benches, and it is possible that the infestation was carried through the summer on this plant. Late in the fall of 1937 the colonies developed much more rapidly and the aphids spread to a number of different plants. During the summer months plants of *Calendula officinalis* growing outdoors in a bed on the east side of the greenhouse were examined several times, but none of these aphids was found there. Small *Calendula* plants placed in infested chickweed did not become infested.

In the greenhouse, feeding and reproduction have been noted on the following plants:

NAME OF PLANT	DEGREE OF INFESTATION
Allium cepa, garden onion	Heavy
Allium fallax	Heavy
Allium recurvatum superbum	Heavy
Allium purdomii	Heavy
Allium sinatum	Heavy
Apium graveolens, celery	Light
Brassica oleracea botrytis, cauliflower	Light
Brassica oleracea capitata, cabbage	Light
Calceolaria sp.	Moderate
Campanula sp.	Moderate
Chionodoxa luciliae	Moderate
Crocus vernus	Light
Dianthus caryophyllus, carnation	Heavy
Iris sp. (variety Wedgewood)	Moderate
Lilium longiflorum	Moderate
Scilla hispanica	Moderate
Stellaria media, chickweed	Moderate
Tulipa sp. (variety Clara Butt)	Heavy
Vinca major variegata	Light
Viola tricolor, pansy	Heavy
Viola sp.	Moderate

These aphids prefer the undersides of the leaves, particularly on plants with broad leaves, although they are frequently found on stems or flowers, fig. 1. They are somewhat sluggish and do not appear to move around much except when the leaf or stem wilts so severely that they must find a new feeding location. Under favorable conditions the reproductive rate is rapid and the aphids can become so numerous that the host quickly succumbs to their attack. The alate forms have been observed more frequently in dense than in sparse infestations, such as those shown in fig. 2.—10-26-38.

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Dryer and Protector for Insects

During the development of the entomological work at the Allegany School of Natural History in Allegany State Park, New York, three difficulties were encountered, all of which were solved with one piece of apparatus.

Since the school is located in the forest, the little white-footed mice, *Peromyscus leucopes noveboracensis*, are common about the buildings. Dried or fresh insects, when left exposed for a few minutes, are likely to be badly damaged, if not completely destroyed by the mice. Carpenter ants, *Componotus herculeanus pennsylvanicus DeG.*, also are very common and they, too, attacked both the unpinned and the pinned insects, often ruining valuable specimens. The first two problems were solved by placing the specimen in a large screen covered cage to exclude ants and mice, but a third problem of slow drying

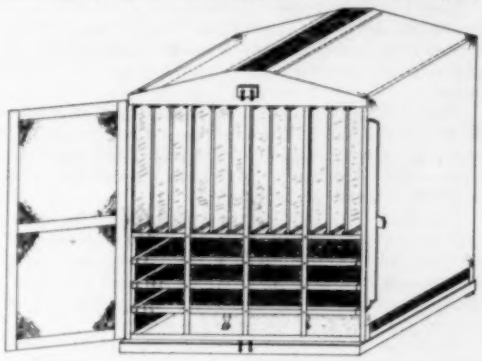

FIG. 1.—Insect dryer and protector.

and the growth of fungus on the specimens soon presented itself.

During certain years, when there is a considerable amount of high humidity and other favorable conditions, the growth of mold on specimens is very common and very destructive.

In an effort to solve all of these problems, the author worked out the following apparatus which was used with considerable success during the rainy summer of 1938. Description of the apparatus is offered here in the hope that it will aid in solving similar problems elsewhere.

The insect dryer and protector, fig. 1, consists of a cage 4 feet wide, 4 feet high and 2 feet 1 inch deep. The frame is made mainly of 2 inches × ¾ inch dressed white pine, with a floor of *Masonite* upon which four to six electric sockets are placed for light bulbs. This frame is covered with carefully fitted copper screen wire which excludes the mice, as well as ants and other insects. Two large doors make it possible to open up the whole front of the dryer when this is desired.

The top portion of the dryer contains twelve pinning boards of brown *Celotex* each 2 inches × 2 feet. Each board fits into a groove at top and bottom, which keeps it in a perpendicular position. Fresh specimens can be pinned on these boards and, depending on the size and water content of the bodies, etc., can be dried in a comparatively short time by the heated air which circulates from the electric lights on the bottom, up through the dryer.

The lower half of the dryer has three shelves upon which spreading boards may be placed to hasten the drying of the Lepidoptera, Orthoptera, etc.

To keep out the dust and to facilitate the complete circulation of air which is warmed where it enters through the screen at the lower part of the dryer, cloth is placed over the wire sides of the cage, covering all of the screen sides with muslin except an area about 2 inches wide all around the bottom of the screen. The top is likewise covered with muslin except a space 6 inches × 24 inches across the middle of the top. This transverse opening across the top of the dryer permits the easy egress of the heated air.

Thus, the air heated by the electric bulbs at the bottom of the dryer must pass up through the shelves containing the spreading boards, and up among the pinning boards, to reach the top where it escapes through the open area across the middle of the top of the dryer.

The slanting top covered with copper screen and muslin, besides protecting specimens from dust, also directs the current of warm air toward the exit.

Since the *Celotex* is easily damaged at its edges, it was found advisable to reinforce the pinning boards by binding the edges with a 3-inch strip of tough, gummed tape such as is used in sealing corrugated boxes.

The apparatus was built by Oscar Waddell of the Buffalo Society of Natural Sciences. The floor, front, back, the doors, shelves and pinning board supports were built separately and then assembled and fastened together with screws.

The floor was first put in place and the front and back fastened in position. Next the successive shelves, etc., from the bottom to the top, were put in position and fastened. The ends and top were then assembled, the doors hung, the fastenings put on and the electrical connections made.

After the dryer was assembled, the muslin cover was thumb-tacked on over the outside of the wire, thus making it possible to take it off easily if it became necessary to put on a new cloth or launder the old one.

The apparatus was placed on a table and as an added precaution, a strip of sticky flypaper was placed around each table leg and the electric wire, to catch any ants or other insects that tried to come up on the table.

The author wishes to express his appreciation for the sketch of the apparatus drawn by Thomas Austin.—1-20-39.

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Derris of High Rotenone Content

It should be of interest to entomologists that derris root of very high rotenone content is now commercially available. Several years ago the governments of both the Federated Malay States and the Dutch East Indies undertook the breeding of high rotenone strains of derris root. In both cases the work has now reached the stage at which such roots are available in appreciable quantities.

Georgi and coworkers (1937) in the Federated Malay States found the race Changi No. 3 of *Derris elliptica* to have exceptionally high rotenone content. They reported as high as 13.0 per cent (on a moisture-free basis) in one sample. It is understood that recently, by further selection, even higher rotenone contents have been obtained. A sample of this race furnished by Georgi and analyzed in the laboratory of the Division of Insecticide Investigations contained 11.7 per cent of rotenone.

In the Dutch East Indies a variety of *Derris elliptica* termed *Toeba wodloeng* was found by Koolhaas and coworkers (1938) to be of high rotenone content. Samples analyzed by them contained as high as 13.4 per cent of rotenone (on a moisture-free basis). A sample representing a commercial shipment from the Dutch East Indies (presumably of this variety) analyzed in the laboratory of the Division of Insecticide Investigations contained 9.2 per cent of rotenone.

In both these varieties the proportion of rotenone to total extractives is high and the average only slightly variable. Thus Koolhaas and coworkers (1938) found the proportion of rotenone to total ether extractives to be about 46 per cent in 10 samples of *Toeba woeloeng*, whereas Georgi and coworkers (1937) found the proportion of rotenone to be 34 per cent in 87 samples of Changi No. 3. In the two samples analyzed in the laboratory of the Division of Insecticide Investigations the proportion was 42 per cent for the Dutch root and 43 per cent for the Malayan root, on the basis of total chloroform extractives. Such roots should be of value in work in which rotenone is the constituent particularly desired.

High rotenone derris root of both British and Dutch origin has recently been imported at New York and is advertised as available in commercial quantities.—2-13-39.

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Methyl Bromide Injury to Apples

In a recent publication, Phillips, Monro & Allen (1938) described internal and external injury to McIntosh apples as the result of fumigation with methyl bromide. It was concluded that the methyl bromide was the only factor in the fumigation process causing injury, which was less severe if the apples were picked at the normal time or if they were fumigated two or more weeks after harvesting.

In the fall of 1938 further observations were made on the effect of methyl bromide fumigation on varieties of apples from different parts of Canada. After picking they were shipped to Montreal and were subjected to a dose of 2.5 pounds of methyl bromide per 1,000 cubic feet of vault space for a period of 90 minutes, with an initial vacuum of 3 inches of absolute pressure dissipated to 28 inches of absolute pressure after the introduction of the gas. The vault temperature was maintained at 80 degrees F. and the fruit temperature ranged from 60 degrees F. to 70 degrees F.

Of the seven varieties treated only two from British Columbia, McIntosh and Jonathan, suffered any injury, which was entirely external. The remaining apples showed no injury of any kind, whether fumigated immediately after arrival in Montreal or after being stored for two weeks. These undamaged varieties were Delicious from British Columbia, Stark and Ben Davis from Nova Scotia, and Rhode Island Greening and Baldwin from Ontario. These preliminary results are thought to be of interest as they may indicate the possibility that apples may be tolerant to methyl bromide fumigation under certain conditions.—2-13-39.

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Two Unusual Species of Aphids Infesting Wheat

Fall wheat in northeastern Colorado, southern Nebraska and adjacent parts of Kansas were reported to be heavily infested the past fall and winter with two species of aphids often mingled together. One of these is *Rhopalosiphum splendens* (Theob.)* described from aphids on wheat in Egypt. The species has been recorded from adjacent regions of Africa on wheat and grasses but has apparently not been recorded heretofore in the United States of America. That it should have attained such numbers before the species was even noticed seems remarkable. An unusual amount of volunteer wheat reported present after harvest in at least the Colorado portion of the infested regions doubtless gave the aphids an opportunity for producing large numbers to attack the planted wheat. This condition partly explains the sudden appearance.

How was the species introduced? Has it a primary host as some kind of tree on which the eggs are laid and on which it could have been transported to this part of the world? It belongs to the *Rhopalosiphum prunifoliae* (Fitch) complex. Primary hosts for this group are apple, *Crataegus*, *Prunus*, *Scirpus* and *Typha*. In the infestation under discussion, however, the aphid seems to be maintaining itself very successfully throughout the year on the wheat and in the viviparous form; no sexuales having been taken. No primary host seems to have been published for this species though very probably one exists.

The other species of aphid involved in the infestation also belongs to the same complex as the former species and, indeed, differs only in color from the typical *Rhopalosiphum prunifoliae* (Fitch). The color of the aphid under discussion is brown instead of the typical green with reddish spots or band in the region of the cornicles.

A remarkable condition in regard to the occurrence of this species in this particular part of the country is the great scarcity of the primary host of *Rhopalosiphum prunifoliae*, the apple and *Crataegus*, in the region of the infestation. Large numbers of fall migrants to return to the winter host would be expected in the fall but the population at the time specimens were sent in, November and December, were predominantly apterous and this in spite of the dessicated condition of the wheat plants which condition has been thought by some workers to increase the number of winged individuals, in certain species at least.

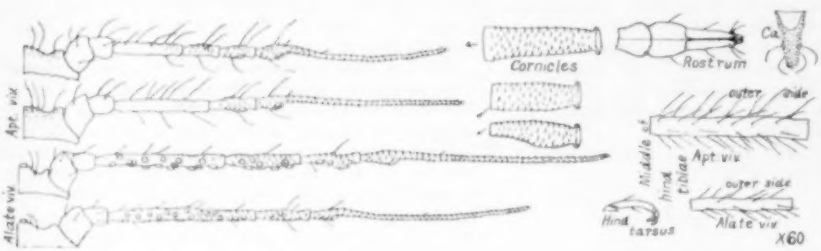

FIG. 1.—*Rhopalosiphum splendens* (Theob.).

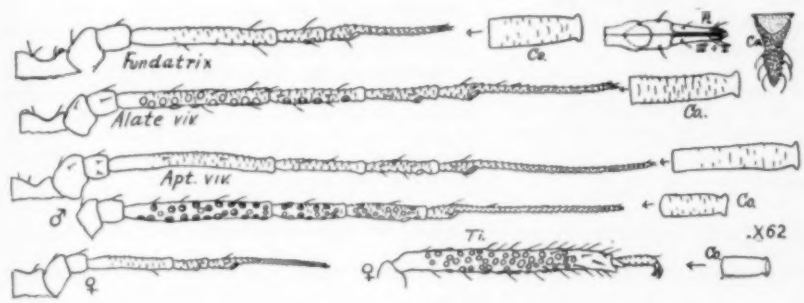

FIG. 2.—*Rhopalosiphum prunifoliae* (Fitch).

The difference in color and apparent independence of the typical, or indeed any, winter host may indicate a distinct race or possibly species, but further study is necessary to settle the question.

Description of *Rhopalosiphum splendens* (Theob.), fig. 1. *Apterous vivipara.*—Medium green, marked with red or orange about and between the bases of the cornicles; antennae, legs, cornicles and cauda dusky to black. Length of body 1.2 to 1.5;† antennae 1; antennal joints as follows: III 0.15 to 0.22, or (III+IV, anastomosed, 0.22 to 0.27), V 0.09 to 0.11, VI 0.06 to 0.07+0.35 to 0.43; hind tibiae 0.65 to 0.68; hind tarsi 0.09 to 0.10; cauda 0.10, bearing 2 pairs of lateral hairs; rostrum attaining first segment of abdomen, joint IV+V 0.13. Hairs erect; on vertex 0.06 to 0.08; on antennae 0.06 to 0.09, on outerside of hind tibiae 0.065 to 0.10; on side of abdomen 0.07 to 0.09. Antennal III and IV generally anastomosed.

Alate vivipara.—Length of body 1.5; hind tibiae 0.85; hind tarsi 0.10; antennae 1.25; joint III 0.20 to 0.29; IV, 0.14 to 0.16 (III+IV anastomosed 0.33),

* Bul. Ent. Res. VI, p. 116, 1915 (Aphis).

† All measurements are in millimeters.

V 0.12, VI 0.07+0.40. Rostrum attaining third coxae or first segment of abdomen, joints IV+V 0.12 to 0.13. Hairs semierect; on vertex 0.03 long, on antennae 0.03 to 0.04 long, on hind tibiae 0.03 to 0.04, on sides of body 0.02 to 0.03. Sensoria on antennal III 12, on IV 7 (on III+IV anastomosed 20); V, 3.

This species differs from *Rhopalosiphum prunifoliae* (Fitch), fig. 2, in the longer and more erect hairs, more than twice as long in apterae, and once and a half in alatae, and the almost constant anastomosing of the third and fourth antennal joints. These characters are specially pronounced and are indeed striking in the apterae. Alate individuals with distinct antennal III and IV are separable only by the slightly greater length of the hairs.

Described from aphids taken as follows: Harlan County, Neb., November 3, 1938, and kindly sent by Raymond Roberts of the University of Nebraska; Julesburg, Colo., December 1, 1938, and sent by F. C. Hale; and Holyoke, Colo., November 21 and December 3, 1938, by A. F. Hoffman, Jr.

The determination was made by comparison with cotype specimens procured by E. O. Essig and kindly loaned by him. Comparison was also made with specimens from Morocco, kindly loaned by J. M. Mimeur.—2-18-39.

MIRIAM A. PALMER, *Colorado Agricultural Experiment Station, Fort Collins.*

Natural Foods of *Cochliomyia americana*, the True Screwworm*

Upon what food or foods do adult flies of *Cochliomyia americana* C. & P. exist in nature? This has been a moot question among investigators of the screwworm. To aid in solving the problem, laboratory experiments were conducted during 1937 and 1938 at Valdosta, Ga.

* The author extends his thanks to E. E. Rogers for assistance during the 1938 experiments.

Fly-rearing cages, 20 inches long, 12 inches high and 12 inches wide, with solid wooden floors and back panels were used for all the experiments. The side and top panels were covered with transparent, fly-proof cloth. The front panel was divided into two parts, a lower square closed by a black cloth sleeve and an upper rectangle closed by wire screen.

Fifty *Cochliomyia americana* pupae, in sand in a shallow glass dish, were placed in each clean cage. When the flies emerged, each cage was provided with a fountain of water and the particular food to be tested. The foods tested included vegetable and animal products. The vegetable products were fresh or slightly rotten fruits and vegetables, either crushed in tap water or sliced without the addition of water. The animal products were offered to the flies with or without a slight amount of tap water. No artificially compounded foods were tested. The food in all except the check cages was either freshened or changed regularly.

All flies that survived the preoviposition period were given the opportunity to deposit eggs. These flies were put in a 4 by 1 inch shell vial containing a piece of storage beef or fresh goat meat, and the vial was placed in an incubator having a temperature of 36 degrees C.; or a pledget of absorbent cotton soaked in the fluid from a wound infested with *Cochliomyia americana* and held in a small glass dish was put into the fly cage. In both cases the egg masses deposited were counted or weighed and reexamined within 24 hours for viability.

Table 1 presents a summary of the foods tested and the results obtained.

No statement on the number of eggs deposited by flies feeding on the various foods has been included because no attempt was made to exhaust the flies of all the eggs they could deposit. Records were kept, however, of all eggs laid by the flies and of the viability of these eggs.

Table 1.—Length of life of *Cochliomyia americana* when fed various vegetable and animal foods, Valdosta, Ga., 1937 and 1938.

Food Tested	Number of Tests	Total Number of Flies in Test		Average Length of Life, Days	
		Males	Females	Males	Females
Sugar (check)	11	230	249	7.7–29.3	7.5–30.6
No food (check)	9	202	169	3.1– 5.9	2.9– 5.2
Vegetable foods:					
Orange	6	96	137	6.3–25.0	5.3–33.1
Pineapple pear	5	136	84	8.0–28.0	7.0–25.8
Watermelon	6	129	95	4.3–18.1	4.8–18.8
Grapefruit	6	116	148	4.8–16.0	5.5–18.0
Wild plum	2	38	47	6.0–13.0	9.0–12.0
Tomato	5	115	110	5.2–11.8	5.0–13.4
Cantaloupe	3	80	52	2.3– 9.0	3.6– 9.0
Black raspberry	2	36	51	4.0– 6.0	4.0– 7.5
Summer squash	1	17	23	3.0– 6.0	4.0– 5.0
Animal products:					
Cow droppings	3	79	66	4.0– 6.0	4.3– 6.0
Mule droppings	2	43	52	4.0– 6.0	4.0– 5.5
Sheep droppings	2	37	59	4.0– 6.0	3.5– 6.5
Goat droppings	2	40	57	4.5– 6.5	4.0– 6.0
Wound fluid	3	66	74	3.6– 6.3	3.0– 5.3
Carcass meat	3	86	59	1.3– 3.6	2.0– 3.3
Cold-storage meat	3	94	48	2.0– 3.3	2.0– 3.3

None of the flies given animal products plus tap water lived through the preoviposition period, which under normal summer temperatures is about nine days, whereas many of the flies given vegetable foods did survive this period. Flies given nothing except tap water lived slightly more than five days. Flies fed on orange closely rivaled sugar-fed flies in the number of eggs deposited. Black raspberry and summer squash were the only vegetables that did not provide sufficient food for the flies to enable them to survive and produce viable eggs.

Some flies in all five experiments with pineapple pear deposited eggs, whereas flies in only three out of six experiments with watermelon, three out of six with grapefruit, two out of five with tomato, and one out of three with cantaloupe deposited eggs. Usually flies fed on watermelon, grapefruit, tomato and cantaloupe deposited viable eggs when the food was freshened every day, but when the food was badly spoiled death occurred within 24 to 48 hours.

There is no doubt that *Cochliomyia americana* is attracted to animal products. Adults at wounds, on dead meats and on animal droppings have been frequently observed under natural conditions by many workers. Even under the conditions of these experiments flies quickly responded to the introduction of fresh animal products into the test cage. Flies were often seen in large numbers on these foods within a few minutes after their introduction. Although *C. americana* seems to feed on these animal products, the food ingested is apparently not sufficient for its needs.—3-2-39.

ARTHUR LOUIS BRODY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

JOURNAL OF ECONOMIC ENTOMOLOGY

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Looking Forward

THE increased number of titles appearing on the programs of the annual meetings of the Association of Economic Entomologists has necessitated a reduction in the time which can be devoted to the presentation of a given paper; hence the importance of its careful preparation. While this has been practiced by most of the members appearing on the programs, it has been too frequently the case in the past that some have failed to complete their remarks in the allotted time, indicating that the manuscripts had been written and laid aside and no attempt made to determine the reading time required in their presentation. Indeed, in a few instances one might be led to believe that the first reading was that made before the meeting of the Association.

Every member who has given any thought to the number of titles appearing on the annual program of the Association must realize the necessity for time limits for the presentation of papers and the strict adherence to those limits on the part of the participant in the interest of the success of the program. It is the duty of the presiding officer to enforce the time limits indicated on the program; it is obviously unfair to permit one speaker to infringe on the time of another. The practice of giving a speaker a minute's warning frequently results in confusion and may have the effect of his omitting one of the most important points of the paper.

The time limit problem can easily be disposed of if the author will read, and if necessary reread his manuscript, for the purpose of determining the number of minutes required under normal conditions in its presentation. If as originally drafted the paper is too long, it will be a simple matter to delete certain unimportant details. In case lantern slides are to be used, the time consumed in showing them should be regarded as part of the time limit set aside for the paper.

The subject of lantern slides and other types of illustrations deserves further consideration. Lantern slides should be presented to the operator in the proper sequence "top side up." The audience should not be required to sit through the painful procedure of waiting while the operator tries to project slides improperly arranged, often upside down. Slides should not be so involved and intricate that they fail to depict readily the points to be illustrated. To this end, they should be given the visibility test before they are exhibited at the meetings.

In the past, other methods of illustration have been employed, such for example as charts on linen, cotton cloth or paper. These, when carefully prepared and of sufficient size, serve a useful purpose but due account of the length of the room should be taken into consideration in their preparation; otherwise those seated in the rear will not be able to follow the discussion intelligently. Regardless of the method to be employed, it should be remembered that it is very disappointing to an audience, in fact an imposition on the time of the members of the Association, to view illustrations which are poorly prepared or which fail to illustrate the points under consideration for more than a few yards beyond the speakers' platform. There should be no occasion for the remark, "It is hoped that those in the rear of the room can see the figures."

If illustrations are not carefully prepared, readily understood and easily seen, it would be preferable to omit them.

In preparing papers for the forthcoming meetings of the Association, the members are requested to take the above suggestions into consideration.—3-15-39.

E. R. Sasscer

REVIEWS

History of American Beekeeping, by Frank Chapman Pellett. 1938. ix+213 pp., illus. Collegiate Press, Ames, Iowa. $2.50.

A good historical background often serves admirably as an aid to an understanding of current affairs in most phases of human activity; hence a history of beekeeping on this continent has been sorely needed. Several persons have considered the preparation of such a work, and at last somebody has been found who was willing and daring enough to carry through the project. It is a simple matter by digging through the voluminous literature on beekeeping to accumulate assorted names and dates, but a far more difficult matter to interpret events and people with right evaluations. The author of this book has had long and intimate association with the beekeeping industry in this country, has to an unusual degree enjoyed personal association with many of the leaders of the craft and is therefore able to discuss past events with a considerable personal background. He wisely declines to evaluate the more recent events and changes, for time alone will permit a proper placing of some of these.

The book is written interestingly in narrative style, with much intimate information regarding men who did most for beekeeping in earlier days. When dates and places are accurately given, as in this book, there is no dispute about facts, and all disagreement will be regarding interpretations and evaluations. Apparently the author over-estimates the influence of some men and occurrences and undervalues others, but this criticism would surely have been leveled at any person who undertook such a book. The conspicuous error of evaluation is regarding Dr. C. C. Miller, who did more than any other person to guide beekeeping through one of its darkest periods. There is implied criticism that Dr. Miller invented none of the gadgets of beekeeping, which is much to his credit. There is in the book too great importance given to equipment and not enough to the development of methods of colony management, which is the outstanding accomplishment of American beekeepers. Since the industry would have been better off if half its equipment had not been discovered, to accuse any beekeeper of failing to invent something may be construed as a high compliment. When some other historian of beekeeping enters this field, he might well devote a chapter to the damage done by some of the equipment.

An author must place a certain limit on size and content of such a book, and there must be a decision regarding what shall be included and what omitted. In this book certain eras through which American beekeeping passed are omitted, due to the fact that the introduction of comb honey production interrupted the development of extracted honey production. No details are given regarding social and economic situations which forced this on beekeeping, due to conditions over which beekeepers had no control. But such an omission is chiefly a matter of interpretation rather than a statement of cold facts, and the author may have done well to leave it to his readers to supply their own interpretations if they have the requisite background.

The book is well written and well illustrated. It can scarcely fail to reveal to its readers the progress which has been made and cause them to look upon some features of the past more critically. As a means of preventing future mistakes by repetition of past blunders, its value is less clear. The book is fittingly dedicated to the Dadant Family, with which the author has long been closely associated, a family which has played a major role in directing trends in the industry. There is unfortunately no index.—11-22-38.

E. F. Phillips, *Cornell University, Ithaca, N. Y.*

The Insects of North Carolina; being a list of the insects of North Carolina and their close relatives, by C. S. Brimley. 560 pp. 1938. North Carolina Department of Agriculture, Division of Entomology, Raleigh, N. C. Price $2.00, cloth bound.

The author and his collaborators are certainly to be congratulated upon this fine list. It introduces a faunal picture of the state which we have not had before and undoubtedly it will be of great value in stimulating the collection and investigation of North Carolina insects. A list of this kind gives a convenient starting point and impetus to similar studies in other states. The preparation of such a publication as *The Insects of North Carolina* is an up-hill battle from the start, involving the gathering and editing of a tremendous amount of data, not to mention the difficult task of obtaining financial backing for clerical work and the actual printing. Listed are 9,581 species of insects, as well as 637 "near" insects (mostly spiders and mites), to form a total of 10,218. Comparing these figures to other state lists, we find that the *List of Insects of New Jersey* (1910) contains 10,385 species, the *Check List of the Insects of Connecticut* (1920) contains 6,781 species, the *List of the Insects of New York* (1928) contains 15,499 insect species and 675 "near" insects. Dr. Brimley estimates that the actual insect species inhabiting North Carolina total over 20,000; it is interesting to note here that in our survey of Illinois insects we have estimated the total Illinois species at 20,000.

This addition to the state lists of insects is especially interesting because of the ecological position of North Carolina. This state contains a remarkable thumb of northern conditions extending into the South; this thumb, the Smokies, has not only northern species reaching south through the mountains, but also species peculiar to that region. To the east lie stretches of piedmont and coastal plain country with their varied, individual habitats. An ecological or topographic account of North Carolina would have been valuable, and the lack of it robs the list of considerable significance except for a person familiar with the state.

Some parts of the list could have been re-edited profitably by specialists acquainted with recent changes in synonymy and generic assignments of particular groups. This same criticism can be made of any comparable list. It indicates, I believe, that the blame must be shared not only by the authors but also to a large measure by the lack of organization of insect taxonomists. Nevertheless, the circumstance should be corrected and authors and taxonomists both should try to make the situation better.

This list fills a wide gap in our knowledge of North American insects in giving us a reference book of insects from a southeastern state. We sincerely hope entomologists of the southeast will continue this worth-while project.—1-18-39.

H. H. Ross, *Illinois National History Survey, Urbana.*

OBITUARY

Wilton Everett Britton 1868–1939

On February 15, 1939, a moderately long and exceedingly rich and helpful life drifted to a close.

Wilton Everett Britton was born at Marlboro, Mass., September 18, 1868, his parents moving to a farm near Keene, N. H., when he was but a year old. He was graduated from what is now the University of New Hampshire in 1893 with the degree of Bachelor of Science. The following year he spent in graduate study at Cornell University. He was awarded the degree of Doctor of Philosophy by Yale University in 1903 and in 1930 the University of New Hampshire conferred upon him the honorary degree of Doctor of Science. He was married April 30, 1895, to Miss Bertha Madeline Perkins of Surry, N. H. They had no children. Mrs. Britton died in 1938. She and Dr. Britton are buried at Surry. Dr. Britton is survived by two brothers, resident at Claremont, N. H., and a sister.

Dr. Britton was appointed as horticulturist of the Connecticut Agricultural Experiment Station May 1, 1894, and in this capacity investigated in collaboration with his chief, Dr. Jenkins, the effects of fertilizers and worked with greenhouse crops, both vegetables and flowers. He experimented in grafting hickory trees in 1896, chestnut trees in 1897, and was ranked as an able botanist. He started nursery inspection in 1898.

The scientific career of Dr. Britton was remarkable in that it included 45 years of public service in the state of Connecticut. For 38 of these years he was State Entomologist and in charge of the Entomological Department of the Agricultural Experiment Station. The writing of 38 comprehensive, well illustrated annual reports on the insects of a state by one man (a thirty-ninth is in preparation if not complete) is a record which has not been equaled, so far as known to the writer. These reports, while primarily economic in character, covered all phases of insect activities, special problems being treated in a number of experiment station bulletins; a particularly important one was the *Plant Pest Handbook. I. Insects.* There were also during this long period many shorter articles in current publications, especially the horticultural and agricultural press.

A number of the more technical contributions of Dr. Britton's department appeared in the publications of the State Geological and Natural History Survey, of which he was Director from 1925 to the time of his death. The contributions in this latter category aided greatly in making the insect fauna of the state more generally known and comprised *A Check List of the Insects of Connecticut, A Guide to the Insects of Connecticut; Part I, A General Introduction; Part II, Euplexoptera and Orthoptera; Part III, The Hymenoptera of Connecticut, Part IV*, an extended volume on the *Hemiptera*, and *Part V*, an excellent account of *The Dragon Flies of Connecticut*. There is a comprehensive manuscript on the Diptera of Connecticut nearly ready for the printer. This phase of his work constitutes by itself a noteworthy series of state publications which were designed to facilitate a general acquaintance with the abundant insect life and smooth the path of both technical and amateur students.

The creation of the office of State Entomologist of Connecticut followed shortly the discovery of the San José scale in the eastern states and led naturally to a state quarantine for the protection of horticultural interests, later to federal action of this character and finally to the creation of regional and federal plant boards which were organized primarily to unify requirements and to make quarantines more workable. Dr. Britton was one of the moving spirits in the organization of the Eastern Plant Board, served on the executive committee for a number of years and was elected President in 1936. The location of a gypsy moth infestation in Connecticut in 1905 was a signal for intensive eradica-

W. E. Britton

tion and repressive work. The appearance in the state of the Japanese beetle, the oriental beetle, the Japanese garden beetle and the European corn borer presented serious problems which required close study and large expenditures in order to secure satisfactory control. The extensive mosquito control richly deserves mention. Dr. Britton cooperated most effectively with federal agencies and those in other states dealing with these problems. These and others were new opportunities for service. The Entomological Department with its well qualified staff, the large collections of insects and photographs and the extensive and well selected library are substantial indications of his objectives.

Insects do not recognize state lines. Dr. Britton was an earnest supporter of national as well as local organizations dealing with problems relating to insects. He was a most faithful attendant of the meetings of the American Association of Economic Entomologists, serving as President in 1909 and also

on a number of important committees. The sections on beekeeping and horticultural inspection held much of interest to him. He gave unstintedly of his time to departures from earlier ways, such as establishing the JOURNAL OF ECONOMIC ENTOMOLOGY (he was Associate Editor from 1910 to 1929) and the publication of *The Index of American Economic Entomology*, numbers I to V, covering the years 1905 to 1934, both undertakings of great value in disseminating and making available the multitudinous records about insects. He was for years one of the active and helpful cooperators of the Crop Protection Institute, serving on the Board of Governors. Some very important and extensive work of this organization was carried on at New Haven under his supervision. He was lecturer in Yale School of Forestry, 1901 and 1905. He also was a Fellow of the Entomological Society of America.

Dr. Britton was elected a member of the American Association for the Advancement of Science in 1904 and a Fellow in 1906. He was a member of many Connecticut organizations, such as the Botanical Society, the Bee Keepers Association, the Forest and Park Association, Pomological Society, Vegetable Growers Association, Library Association. He, more than any other, was responsible for the organization of the Connecticut Tree Protective Association. From its organization he was chairman of the Connecticut Tree Protection Examining Board and was a member for more than 20 years of the National Malarial Committee.

Dr. Britton's interests in local organizations is indicated by his serving as President of the Edgewood Civic Association in 1908 and again in 1920. He organized and served as Director and President of the Donald G. Mitchell Library; he was Director, 1925–1932, of the New Haven Public Library, Director since 1912 of the Young Men's Institute Library. His deep interest in the published record is also shown in the unusually complete library of the Entomological Department assembled under his guidance. His stability is suggested by his membership for 40 years in the Indian River Grange in Milford. He was Chairman of the Committee on Food, New Haven War Bureau, during the World War, and a member of the Governor's Foot Guard, 2nd Company, April, 1917, to December, 1920.

He was awarded honorary recognition as one of the leaders in agricultural and rural life at Farm and Home Week, July 30, 1936, at the Connecticut State College. As Director of the State Geological and Natural History Survey, he was responsible for the editing and publication of a wide series of contributions to the natural history of Connecticut.

Dr. Britton enjoyed to an unusual degree the confidence and affection of his associates. Few realize the wide scope of his activities and the influence he has exerted. He was not limited by state lines. He did much to stabilize quarantine and other policies of both federal and other state officials. His work will continue to influence entomological activities for many years. All who knew him have lost a highly esteemed and greatly respected friend.—3-13-39.

—E. P. FELT

CURRENT NOTES

ANNUAL MEETING OF COTTON STATES BRANCH

The fourteenth annual meeting of the Cotton States Branch of the American Association of Economic Entomologists was held in Tampa, Fla., February 21–23, 1939, at which more than 50 papers were presented. The program included a symposium on citrus pests and an all day tour of central Florida to observe spraying and other practices in connection with the citrus industry.

The attendance was larger than that of any previous meeting of the Branch. There were many features of entertainment, including the annual banquet at a Spanish restaurant, an entomologists' trophy dog race and tours. A special feature was the three-day program provided for the entertainment of the ladies. Officers elected for the ensuing year were Oliver I. Snapp, Fort Valley, Ga., Chairman; L. L. English, Spring Hill, Ala., Vice-Chairman; John T. Creighton, Gainesville, Fla., Secretary-Treasurer.

The next annual meeting of the Branch will be held at the time and place of the meeting of the Association of Southern Agricultural Workers.

EASTERN AWARD MEDAL

To E. H. Siegler and Lyle D. Goodhue, both of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, went the first award medal of the Eastern Branch, American Association of Economic Entomologists. The medal was awarded for what the judges considered the outstanding contribution to the science of economic entomology for the year 1938 made by members of the Eastern Branch.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
EASTERN BRANCH
FOR NOTABLE CONTRIBUTION TO THE SCIENCE OF ECONOMIC ENTOMOLOGY

Annual Medal, Eastern Branch, American Association of Economic Entomologists, awarded in 1938 to E. H. Siegler and Lyle D. Goodhue.

A report of the contribution made by Siegler and Goodhue is contained in their paper, "Effect of Particle Size of Some Insecticides on Their Toxicity

E. R. Sasscer, left, President of the American Association of Economic Entomologists, and E. N. Cory, Secretary and Treasurer.

to the Codling Moth Larva," published in this issue of the JOURNAL OF ECONOMIC ENTOMOLOGY.

In selecting the paper for the award the judges considered form, style and correctness of language, clarity of presentation and interpretation of data, and soundness of conclusions drawn, as well as the importance of the paper as a contribution to the science of economic entomology.

Medals were awarded to both Siegler and Goodhue, as provided by the committee which drew up regulations covering the award. The medal is the work of R. J. Sim.

PROCEEDINGS OF THE TENTH ANNUAL MEETING EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Lord Baltimore Hotel, Baltimore, Md., November 17 and 18, 1938

The meeting was called to order by Vice Chairman C. C. Hamilton. Mr. Lee A. Strong, Chief of the Bureau of Entomology and Plant Quarantine, extended greetings from his Bureau. Mr. J. J. Davis, President of the American Association of Economic Entomologists, brought a welcome from the national association and also described the other branch meetings that he had attended, bringing out the advantages of formal and informal meetings and the facilities for discussion and pleasure that the latter combined.

Mr. V. I. Safro, Chairman, then conducted the regular sessions for the reading of papers and discussions. The interest at all sessions was good. Approximately 200 attended. A very successful "Symposium on Household Insects" was arranged and conducted by Mr. Neely Turner on the afternoon of November 17. Many members of the National Pest Control Association attended this symposium.

The Eastern Branch program contained 37 titles, and with two exceptions, all papers were presented.

In the following account the proceedings of the two business sessions have been combined.

The Chairman, Mr. V. I. Safro, appointed the following committees:

Committee on Nominations: Hugh Glasgow, S. W. Bromley.

Auditing Committee: G. F. MacLeod, I. L. Ressler.

Table 1.—Dues received from Eastern Branch members in 1937 and previous years.

STATE	1929	1930	1931	1932	1933	1934	1935	1936	1937
West Virginia	1	1	1	2	2	2	3	0	1
Virginia	5	4	8	5	4	5	9	3	8
District of Columbia	6	3	0	2	5	6	14	7	8
Maryland	5	6	9	3	4	5	9	6	7
Delaware	2	2	3	1	2	5	5	7	5
Pennsylvania	9	3	11	5	15	13	12	7	8
New Jersey	26	21	19	11	23	20	23	19	22
New York	27	28	39	25	23	25	26	33	35
Connecticut	10	9	15	5	6	7	7	10	8
Rhode Island	2	0	1	0	0	0	1	1	1
Massachusetts	6	5	14	8	4	3	4	3	3
Vermont	1	1	0	0	0	0	1	0	1
New Hampshire	0	0	1	1	0	0	0	0	0
Maine	0	1	2	1	0	1	2	1	1
Canadian Provinces	1	0	0	0	0	0	1	0	0
Outside Eastern Branch Territory	0	0	0	0	0	0	0	3	2
TOTAL	101	84	123	69	88	92	117	100	110

Committee on Resolutions: J. A. Hyslop, H. F. Dietz, L. A. Stearns.

The report of the Secretary-Treasurer was presented and referred to the Auditing Committee.

REPORT OF THE SECRETARY-TREASURER

A record of the dues received from Eastern Branch members in 1937, together with similar information for previous years is shown in table 1.

FINANCIAL STATEMENT

Balance on hand, November 10, 1937		$2,047.37
Receipts		
Additional dues for 1937	$160.00	
Receipts due to sale of Directories	214.81	
Dues for 1938 (To November 10, 1938)	56.00	
Interest on Savings Account	7.50	
Total Receipts	438.31	$2,485.68
Disbursements		
Lantern operator, Philadelphia meeting	$ 30.00	
Clerical services—Eastern Branch	18.25	
Clerical services—Directory	27.70	
Postage—Directory	51.00	
Postage—Eastern Branch	24.84	
Printing—1937 Proceedings of Branch	369.00	
Printing, programs Philadelphia meeting	24.75	
Printing—in connection with Directory	21.50	
Printing—notices of Award	19.75	
Stationary, Eastern Branch	10.25	
Expenses of Secretary-Treasurer	12.10	
Gold Medals and die	98.50	
Total Disbursements		707.64
Balance on hand, November 7, 1938		$1,778.04
Distributed as follows:		
Acct. No. 17424—Trenton Trust Co.	$1,007.50	
Checking Account—Trenton Trust Co.	770.54	
	$1,778.04	

HARRY B. WEISS
Secretary-Treasurer

The following report of the Finance Committee was read and adopted:

REPORT OF THE FINANCE COMMITTEE
From 11-1-37 to 11-1-38

This report does not include copies of the Second Edition of *Entoma* sent out to members of the American Association of Economic Entomologists or members of the Eastern Branch of the American Association of Economic Entomologists.

Copies of 1935 Edition *Entoma* sent out gratis	3		
Copies of 1937 Edition *Entoma* sent out gratis	26		
Cash Receipts			
Copies of First Edition *Entoma* sold for 50 cent each	10	$ 5.00	
Copies of Second Edition *Entoma* sold for 50 cents each	32	16.00	
Copies of Second Edition *Entoma* sold for 75 cents each	242	183.00	
Copies of Second Edition *Entoma* sold for $1.00	4	4.00	
Postage received in cash		0.10	
Total cash receipts for *Entoma*			$208.10
Receipts in Stamps			
Copies of Second Edition *Entona* sold for 50 cents each	4	$ 2.00	
Copies of Second Edition *Entoma* sold for 75 cents each	21	15.75	
Copies of Second Edition *Entoma* sold for $1.00 each	None		
Total stamp receipts for *Entoma*			17.75

Cash Due

Copies of Second Edition *Entoma* sold for 50 cents each	1	$ .50		
Copies of Second Edition *Entoma* sold for 75 cents each	12	9.00		
Copies of Second Edition *Entoma* sold for $1.00 each	1	1.00		
Total cash due			10.50	
			$236.35	

Cash Statement

Balance from 11-1-37		$ 5.00		
Received from Mr. Weiss for Stamps		51.00		
			56.00	
Grand Total				$292.35

Disbursements

Cash sent to Mr. Weiss		$163.50		
Checks sent to Mr. Weiss		6.00		
Cash used for stamps	$58.00			
Express	3.54	61.54		
Cash on hand		33.06		
Stamps used which were received in payment for *Entoma*		17.75		
Total Disbursements			$281.85	
Cash due			10.50	
Grand Total				$292.35

CLYDE C. HAMILTON
Chairman

The following report of the Committee on Annual Award was adopted:

"At the final business session of the Annual Meeting of the Eastern Branch, on November 19, 1937, the following motion was passed:

'That an annual medal be awarded to the member of the Eastern Branch for that paper presented at the Annual Meeting of the Branch, that shall represent, in the opinion of the judges, to be appointed each year by the Chairman of the Branch, the best contribution to the Science of Economic Entomology.

'For this purpose the Chairman of the Eastern Branch shall appoint a Committee of three members to establish the conditions under which the award shall be made, the rules of eligibility of papers, details as to manuscripts and their publication, the value, and nature and purchase of the medal and such other matters in connection therewith as will permit the granting of the annual award to begin with the Annual Meeting in 1938.

'The conditions as established by the Committee shall be transmitted to the Secretary of the Branch who will announce them to the Membership as soon as practicable.'

"In accordance with this motion, a committee on Annual Award was appointed by the Chairman of the Eastern Branch, American Association of Economic Entomologists, V. I. Safro, the Committee consisting of C. H. Hadley (Chairman), P. J. Chapman and William Moore.

"The duties of the Committee are 'to establish the conditions under which the award shall be made, the rules of eligibility of papers, details as to manuscripts and their publication, the value, nature and purchase of the medal, and such other matters in connection therewith as will permit the granting of the Annual Award to begin with the Annual Meeting in 1938,' and to transmit to the Secretary of the Branch the conditions as established by the Committee, these conditions to be announced to the Membership by the Secretary as soon as practicable.

"The Committee therefore, in accordance with its instructions, reports as follows:

Conditions

"(1) *Eligibility.* Competition for the Award shall be limited to members of the Eastern Branch, American Association of Economic Entomologists, in good standing for the fiscal year current; *i.e.*, the year commencing November 1 prior to the date of the Annual Meeting of the Branch.

"(2) *Submission of Papers.* Papers must be submitted to the Secretary of the Eastern Branch prior to or at the time the papers are to be presented at the Annual Meeting. Each paper must be submitted in duplicate, one copy for publication and the second copy for the Judges.

"(3) *Papers.* The manuscript must be typewritten on standard letter size sheets, in English, in duplicate, each copy accompanied by all necessary photographs, drawings, diagrams and tables, and in form suitable for publication. Unless already included in the manuscript, each paper must also be accompanied by a summary of the data presented and conclusions reached.

"(4) *Selection of Paper for Award.* In the selection of the paper for the Award, the Judges shall give consideration to form, style and correctness of language, clarity of presentation and interpretation of data, and soundness of conclusions drawn, as well as the importance of the paper as a contribution to the Science of Economic Entomology. The Judges shall report their decision to the Chairman of the Eastern Branch not later than the 15th of December following the Annual Meeting. The Chairman of the Eastern Branch shall certify to the President of the American Association of Economic

Entomologists the name of the author and title of the paper selected for the Award. In the event that more than one name appears as author of the paper selected by the Judges for the Award, each co-author who otherwise is eligible shall receive a medal, and the cash award shall be divided equally among the eligible co-authors.

"(5) *Award.* The Award shall consist of a medal, suitably engraved with the name of the recipient and date, and a cash award in the amount of $75.00. The Award shall be presented to the recipient at the Annual Meeting of the American Association of Economic Entomologists next following the Eastern Branch Meeting, by the President (or Acting President) of the American Association of Economic Entomologists in behalf of the Eastern Branch, and appropriate citation shall be published in the JOURNAL OF ECONOMIC ENTOMOLOGY.

"(6) *Publication.* The paper winning the Award shall be published in the JOURNAL OF ECONOMIC ENTOMOLOGY as a paper of the Eastern Branch, and shall be accompanied by the statement: 'Awarded the Annual Medal of the Eastern Branch, American Association of Economic Entomologists, for the year .'

"(7) *Medal.* The Committee has selected a suitable design for the medal, the design having been drawn at the request of the Committee by Mr. R. J. Sim. The motion of the Eastern Branch of November 19, 1937, carries with it full authority to incur for the Association such expenses as are necessary to carry out the purpose of the motion, and the Committee has, therefore, with the concurrence of the Chairman of the Eastern Branch, taken appropriate steps to secure the die and medal for 1938."

THE COMMITTEE:
C. H. HADLEY, *Chairman*
WILLIAM MOORE
P. J. CHAPMAN

REPORT OF AUDITING COMMITTEE

We have audited the accounts of the Secretary-Treasurer and find them to be correct.

G. F. MACLEOD
I. L. RESSLER

Following the adoption of the above report, the Branch adopted the report of the Secretary-Treasurer.

REPORT OF THE COMMITTEE ON RESOLUTIONS

Your Committee on Resolutions recommends the adoption of the following resolutions:

(1) Be it resolved, that the Eastern Branch extends its thanks to the Local Committee for the excellent arrangements and facilities for this meeting by a rising vote and that a copy of this resolution be transmitted to the management of the Lord Baltimore Hotel.

(2) That this Branch express its appreciation of the opening addresses made by the Chief of the Bureau of Entomology and Plant Quarantine and the President of the Parent Association.

(3) That the Eastern Branch commends the Finance Committee on its general activity and especially on its accomplishments in the publication of *Entoma*.

(4) That the Eastern Branch is gratified with the work of the Committee on the Annual Award and the selection of a suitable medal.

(5) That this Branch recommends to its members their attendance at the forthcoming Richmond Meetings.

J. A. HYSLOP
H. F. DIETZ
L. A. STEARNS

The above report and also the following one from the Committee on Nominations were adopted by the Branch.

REPORT OF COMMITTEE ON NOMINATIONS

For Chairman, Clyde C. Hamilton
For Vice-Chairman, G. F. MacLeod.

HUGH GLASGOW
S. W. BROMLEY

The following members and guests registered during the meetings:

Albert, Talbot J.
Alexander, C. C.
Amos, J. M.
Anderson, Lauren D.
Arnold, R. B.
Ayres, D. W.
Badertscher, A. L.
Bailey, Harold L.
Bartlett, F. J.
Baumhofer, L. G.
Beckwith, C. S.
Becnel, I. J.
Bender, A. H.
Benmosche, Jack
Bickley, William E., Jr.
Bishopp, Fred C.
Blauvelt, W. E.
Braure, L. L., Jr.
Brennan, James M.
Bromley, S. W.
Buchholz, A. B.
Buettner, William O.
Bulger, J. W.
Bungay, Alfred
Byrne, J. R.
Campbell, F. L.
Carman, Glenn E.
Cavenaugh, L. A.
Cissel, P. Calvert
Collins, C. W.
Cory, Ernest N.
Craig, F. Waldo
Crosthwait, S. L.
Crowell, H. H.
Cupples, H. L.
Darley, Merrill M.
Davidson, W. W.
Davies, Caleb, Jr.
Davis, J. J.
Dawsey, L. H.
Dean, R. W.
Dietz, Harry F.
Ditman, L. P.
Donahue, William B.
Driggers, B. F.
Drucker, Irving H.
Dye, H. W.
Eaton, N. A., Jr.
Elliott, William A.
Ehrlich, J. C.
Faxon, Richard
Feinson, David
Felt, E. P.
Fenton, Alfred
Fennenian, Tosyl
Ferguson, William C.
Filmer, Robert S.
Fleming, Walter E.
Friend, R. B.
French, G. T.
Gemmell, Louis G.
Ginsburg, J. M.
Glasgow, Hugh
Glass, Sidney S.
Goddin, A. H.
Goodhue, Lyle D.
Granett, Philip
Guy, H. G.
Hadley, C. H.
Haller, Herbert L. J.
Hamilton, C. C.
Hammer, D. H.
Harris, Lewis P.
Hartzell, F. Z.
Headlee, T. J.
Hess, Jacques J.
Hoffman, C. H.
Horsfall, J. L.
Horwitz, Elaine
Hough, W. S.
Hubbell, F. D.
Hutton, Richard W.
Hyslop, J. A.
James, W. S.
Jones, M. P.
Joyce, R. F.
Kaufmann, Byron
Kelley, R. J.
Kidwell, A. S.
King, J. L.
Kopf, Joseph C.
Langford, G. S.
Latta, Randall
Leonard, M. D.
MacCreary, Donald
MacLeod, G. F.
Madden, J. P.
Maude, W. J.
MacCloud, Walter
McConnell, H. S.
McGovran, E. R.
McIntyre, Henry L.
Mell, C. W.
Meyers, Herbert

Meyer, Martin G.
Miller, A. C.
Nelson, F. C.
Noble, Harold
Norris, John
Nottingham, J. O.
O'Reilly, William
Osborn, H. T.
Peairs, L. M.
Pepper, B. B.
Pepper, J. O.
Phillipp, Leopold
Pierpont, Roger L.
Poos, F. W.
Porter, B. A.
Porter, C. Walter
Powers, George E.
Rauck, W. A.
Rawlins, W. A.
Reed, L. B.
Ressler, I. L.
Rex, Edgar G.
Richardson, H. H.
Ritt, A. E.
Roark, R. C.
Roney, J. N.
Rosen, S. S.
Rosenfeld, H. A.
Safro, V. I.
St. George R. A.
Sameth, H. G. Irving
Sameth, J. Edwin
Sheain, G. A.
Shrimplin, W. J.
Simanton, W. A.
Smith, Charles M.
Smith, C. R.
Smith, Floyd F.
Smith, L. E.
Soraci, F. A.
Stearns, L. A.
Steiner, H. M.
Stene, A. E.
Stonebraker, B. H.
Stover, Gilbert W.
Strong, Lee A.
Strong, John C.
Stucker, Harry
Summerland, S. A.
Tompkins, K. W.
Turner, Neely
Vogel, Lothar
Vogel, John G.
Wade, J. S.
Wadley, F. M.
Walker, G. L.
Walker, Harry G.
Wagner, W. E.
Weiss, H. B.
White, W. H.
Whitten, R. R.
Whittington, F. B.
Willey, C. R.
Wilson, Charles S.
Wimmer, Sidney
Wood, W. B.
Worthley, H. N.
Zappe, M. P.